3.0 RESULTS

This section describes the results of the information gathering efforts undertaken during the course of the project. Emphasis was placed upon obtaining geobased data, particularly in the form of segmentation maps and maps of distributions of various parameters and features valuable in the assessment of the segmentation of an estuary. The major sources of information are discussed below. The information described below constitutes the bulk of that synthesized in the decision matrix presented in Section 4 of this report. In addition, information of a very specific nature and applicability was obtained, particularly from the mailout effort, and is referenced in the bibliography or one of the databases described previously.

3.1 Texas Water Commission

On September 1, 1985, the Texas Water Commission (TWC) assumed primary responsibility for protecting Texas' water resources as a result of Senate Bill 249 enacted by the 69th Texas Legislature (TWC, 1990a). This legislation abolished the Texas Department of Water Resources and transferred most of its functions to the TWC. The TWC currently has the primary responsibility for implementing the regulatory statutes and laws relating to Texas waters. The agency is responsible for implementing State laws relating to water and for enforcing all rules, standards, orders, permits, licenses, and laws under its jurisdiction.

3.1.1 TWC Stream Segmentation

All major water bodies in the state of Texas have been delineated into segments by the Texas Water Commission (TWC) as part of the water quality inventory mandated by section 305(b) of the Federal Clean Water Act. TWC segmentation for Galveston Bay and the Houston Ship Channel are shown in Figures 3 and 4, respectively. The purpose is to assess, on a continuing basis, the water quality of individual systems that can be segregated based on relatively homogeneous characteristics.

Designations assigned by the TWC to describe a segment include classifications and uses. Segment classifications include "water quality limited" or "effluent limited" designations. A segment is considered water quality limited if any of the following conditions are true:

- Stream monitoring data have shown significant violations of water quality standards as established by the Texas Surface Water Quality Standards.

- Advanced wastewater treatment for point sources of wastewater discharges is required to meet water quality standards or to protect existing conditions of exceptional water quality. Advanced treatment is defined as "treatment equal to or more stringent than the 30-day average of 10 mg/L BOD_5 and 15 mg/L NH_3-N".

- The segment is a reservoir for a domestic water supply.

All segmented waters that are not classified as "water quality limited" under the previous criterion are classified as "effluent limited" for which conventional wastewater treatment is adequate to protect existing waterbody conditions (TWC, 1990b).

These designations are determined based on water quality standards established by the TWC for the purpose of maintaining desirable uses. Numerical criteria are developed to maintain those designated uses. Designated uses are determined by taking into account a waterbody's physical characteristics, natural water quality, and actual uses. The nine categories of designated uses pertaining to the Galveston Bay system are contact recreation, non-contact recreation, limited quality aquatic habitat, high quality aquatic habitat, exceptional quality aquatic habitat, shellfish waters, industrial water supplies, navigation, and public water supply waterbodies.

Protection of the designated uses in the State of Texas is based on employing various regulatory actions to assure these uses are attainable including setting limits on the quantity of pollutant loadings from point source discharges, setting standards for water quality that must be maintained in the waterbody, and taking enforcement action against violators.

3.1.2 Statewide Monitoring Network

The Statewide Monitoring Network (SMN) database is a repository for all data collected by the Texas Water Commission and includes physical, chemical, and biological information. The monitoring network is coordinated by the Water Quality Standards and Evaluation Section and is carried out by the agency's Field Operations Division. Data stored in the SMN database are utilized by staff members in prioritizing and developing waste load evaluations to determine water quality effects of pollutant discharges. These data are available to those outside the TWC through the Texas Natural Resources Information System (TNRIS).

3.1.3 Clear Lake Board Order

The Texas Department of Water Resources (TDWR) prepared a staff report Board Order in October 1980 for the purpose of assessing future measures requiring implementation for protection of the Clear Lake watershed (TDWR, 1980). Information gathered during the study included ambient nutrient concentrations for the Clear Lake drainage area and the locations of wastewater permittees in the Clear Lake drainage. That report concluded that Clear Lake is nitrogen limited, Galveston Bay is the dominant source of phosphorous in Clear Lake, and that advanced wastewater treatment levels will be necessary to maintain dissolved oxygen levels and protect water quality in Clear Lake and its tributaries.

3.2 Texas Parks and Wildlife Department

The Parks and Wildlife Code states that Texas Parks and Wildlife Department (TPWD) is the State agency with primary authority for protecting the fish and wildlife resources of the State. As a result, TPWD has implemented a variety of programs to collect and manage data for the purposes of developing rules and regulations to protect fish and wildlife resources in Texas.

For the purposes of managing the fisheries resources in Texas, the TPWD in cooperation with the National Marine Fisheries Service (NMFS), collects landings data from recreational and commercial fishermen. These data are collected to assess the need for and the impact of saltwater fishing regulations (Quast et al., 1988). Texas commercial landings are reported for

the Gulf of Mexico and bay systems which include Sabine Lake, Galveston Bay, Matagorda Bay, East Matagorda Bay, San Antonio Bay, Aransas Bay, Corpus Christi Bay, upper Laguna Madre, and lower Laguna Madre. Finfish landings by sport-boat fishermen are further subdivided into minor bays within the major bay systems (Osburn et al. 1988). The minor bays within the Galveston Bay System appear in Table 1.

Since 1975, the TPWD has conducted a Marine Resource Monitoring Program. According to the TPWD Coastal Fisheries Branch Marine Resource Monitoring Operations Manual for 1991, the purpose of this program is to determine and monitor trends in species composition, size, and relative abundance for selected finfishes and shellfishes in coastal systems and in the Gulf of Mexico. Field measurements are made for temperature, dissolved oxygen, salinity, and turbidity. The TPWD does not return to fixed stations; instead, sampling locations are randomly selected in order to eliminate long-term bias in the data that might result from continued sampling of the same stations. The Galveston Bay system is defined in the Operations Manual as follows:

> "All waters, including all saltwater bayous, bounded by a line behind the surfline from the bridge over the ICWW at High Island to the southwestern shoreline of Drum Bay and the north edge of Trinity Bay where the Trinity River enters the bay. On 21 November 1982, the area between the Baytown tunnel and the junction of the San Jacinto River and the Houston Ship Channel was added to the Galveston Bay System."

Each bay system is then subdivided into a grid of one-minute cells, each of which is designated according to the most appropriate gear type. In the field, the designated gear type is further subdivided into a 12 x 12 network of "gridlets"; each gridlet is five seconds on each side. All species greater than five millimeters in length are identified to species level and counted. Subsets of some fish species are weighed and measured according to procedures in the Operations Manual. As of June 1990, there were 12,000 records (i.e., station date-entries) for Galveston Bay.

TABLE 1

MINOR BAYS WITHIN THE GALVESTON BAY SYSTEM, THE TEXAS PARKS AND WILDLIFE DEPARTMENT

Galveston Bay System
Alligator Lake
Ash Lake
Bryan Lake
Bastrop Bay (includes Bastrop Bayou downstream from junction with Austin Bayou)
Burnett Bay
Black Duck Bay
Carancahua Lake
Cedar Lakes
Cotton Lake
Crystal Bay
Bolivar Roads (east of a line between the ferry landing on Port Bolivar to range marker at the Coast Guard station at Fort Point to the end of the jetties)
Quintana Channel (area between the ICWW southeast to the end of the jetties)
Chocolate Bay
Choctaw Lake
Christmas Bay
Clear Lake (includes Clear Creek downstream from the bridge on Highway 3)
Crab Lake
Cox Lake
Dickinson Bay (included Dickerson Bayou downstream from bridge on St 146))
Dollar Bay
Drum Bay
Cow Trap Lakes
East Bay (also includes all waters from bridge over ICWW at High Island to junction of ICWW East Bay)
Freeport Bay Area
Galveston Bay
Green's Lake
Hall's Lake
Horeshoe Lake
Hall's Lake (includes Highland Bayou downstream from the railroad bridge that connects Texas City with the GC&SF railroad)

Galveston Bay System (continued)
Horeshoe Lake
Jones Lake (Freeport area)
Lake Como
Lost Lake
Lost Bay
Moses Lake
McNeal Lake
Mud Lake
Nicks Lake
Oyster Lake (near Bastrop Bay)
Oyster Creek
Old Brazos River (from end of harbor to junction with ICWW)
Oyster Lake (Bolivar Peninsula)
Pelican Lake
Swan Lake (Freeport area)
Rollover Bay
Salt Lake
Swan Lake (Galveston area)
Tabb's Bay
San Jacinto Bay
Scott Bay
Taylor Lake
Sweetwater Lake
Trinity Bay (includes Trinity River Delta south of Big Hog Bayou)
West Bay
Rollover Pass (area between junction with Rollover Bay and surfline)
San Luis Pass (area 1/2 mile bayward and 1/2 mile Gulfward off the Vacek bridge)
San Bernard River (includes all water junction with the Gulf)
Brazos River (includes all waters downstream from the Dow Chemical floodgate to the junction Gulf)

Chapter 77 of the Parks and Wildlife Code addresses TPWD shrimping regulations. According to §77.001, Trinity Bay, Galveston Bay, East Galveston Bay, and West Galveston Bay, exclusive of tributary bays, bayous, and inlets, lakes, and rivers, are defined as major bays. Nursery areas are defined as tributary bays, bayous, inlets, lakes, and rivers which are proven to serve as significant growth and development environments for postlarval and juvenile shrimp not including the outside waters, major bays, or bait bays. Bait bays are defined as including major bays. That portion of Chocolate Bay and West Galveston Bay north of the Gulf Intracoastal Waterway in Brazoria County is defined as a bait bay in the 1990-1991 Fiscal Texas Commercial Fishing Guide. The boundaries between bays are not defined any more specifically than this.

Oyster data are also collected in the TPWD Resource Monitoring Program. In addition, the location of major oyster reefs in Galveston Bay, Trinity Bay, and East Bay have been mapped by the TPWD (Benefield and Hofstetter, 1976) and are reproduced in Figure 5. The TPWD has not mapped oyster reefs in West Galveston Bay although there are many present there (Richard L. Benefield, TPWD, personal communication).

Two TPWD wildlife management areas (WMA) are located within the Galveston Bay System: Atkinson Island and Candy Abshier (Charlie Winkler, TPWD, personal communication). Atkinson Island WMA is part of an 152-acre spoil island located adjacent to the Houston Ship Channel near Morgan's Point. Candy Abshier WMA includes 205 acres of land and two acres of water located within Smith Point, Texas.

Active colony sites for breeding pairs of colonial waterbirds observed in 1990 for counties surrounding Galveston Bay were considered for this segmentation report. This information was obtained from a report prepared by the TPWD and the Texas Colonial Waterbird Society (1990). Four colonies were located in Chambers County, 31 in Galveston County and four in Harris County (Table 2).

TABLE 2

COLONIAL WATERBIRD NESTING LOCATIONS IN

CHAMBERS, GALVESTON, AND HARRIS COUNTIES FOR 1990

Colony Number	*Colony Name*	*Number of Species*	*Number of Breeding Pairs*
Chambers County			
600-054	Catfish Acres	5	870
600-120	Trinity River Mouth	6	3,320
600-140	East of Lost Lake	4	425
600-260	Vingt-et-un Island	9	380
Galveston County			
600-051	Scholes Field	1	80
600-240	Redfish Island	2	40
600-261	Smith Point Island	12	1,602
600-300	Rollover Pass	10	1,438
600-340	Moses Lake Spoil Islands	4	82
600-341	Dickinson Bay Spoil Island	2	550
600-381	Bolivar Flats	1	2
600-422	Marker 52 Spoil Island	1	30
600-423	Jigsaw Island	2	270
600-424	North Deer Island	14	4,829
600-425	Down Deer Island	1	70
600-426	South Deer Island	7	620
600-427	Ganges Bayou	1	62
600-442	Little Pelican Island	15	15,574
600-443	Pelican Island	4	10,448
600-444	Fort San Jacinto	1	4
600-447	Maginolia Compress #15	1	4
600-449	Farmers Copper	1	50

TABLE 2

COLONIAL WATERBIRD NESTING LOCATIONS IN CHAMBERS, GALVESTON, AND HARRIS COUNTIES FOR 1990 (CONTINUED)

Colony Number	*Colony Name*	*Number of Species*	*Number of Breeding Pairs*
600-522	McAllis Point	1	20
600-523	Maggies Point	3	230
600-524	Snake Cove Point	2	26
600-526	Bay Harbor Bar	4	330
600-541	Oxen Bayou Point	2	90
600-542	Mensell Bayou Point	6	823
600-543	Starvation Point	2	17
600-544	Eckert Bayou Point	4	613
600-545	Hoeckers Point	2	85
600-546	Dana Cove	1	25
600-547	Carancahua Cove	6	682
600-548	Live Oak Grove	1	4
600-580	San Luis Pass	2	210
Harris County			
600-001	Sheldon Reservoir	5	1,110
600-160	Baytown Tunnel	2	60
600-161	Alexander Island	10	793
600-163	Exxon Baytown North Gate	1	32

3.3 Texas Department of Health

Chapter 436 of the Health and Safety Code allows the Commissioner of Health to close any polluted area to the taking of shellfish, which is defined as oysters, clams, and mussels. A polluted area is defined as an area that is continuously or intermittently subject to the discharge of sewage or other wastes or to the presence of coliforms in quantities likely to indicate that shellfish taken from this area may be unfit for human consumption. This chapter further states that the Commissioner shall outline polluted areas on maps. The maps indicating polluted areas for Galveston Bay appear in Figure 6. These maps are segmented or divided into three areas:

- Approved Areas
- Conditionally Approved Areas
- Polluted Areas

According to the Texas Department of Health (TDH, 1990), polluted areas are closed to the harvesting of shellfish. Conditionally approved areas are subject to classification changes based upon meteorological conditions. All other areas not specifically defined as either polluted or conditionally approved are approved for the harvesting of shellfish. This segmentation or classification system for shellfish is subject to change by the TDH at anytime due to rainfall and runoff, flooding, hurricanes, or other extreme weather conditions. Failure or inefficient operation of wastewater treatment facilities may also result in changes (TDH, 1990).

3.4 Texas General Land Office

Information obtained from the Texas General Land Office (GLO) included oyster reef locations, state land tract boundaries, and dredge spoil disposal locations. This information was provided in the form of an ARC/INFO file that was transferred to the JN GIS system. Figure 7 is a map of the GLO land tracts within the Galveston Bay system. Dredge spoil areas are shown in Figure 8.

3.5 Texas Water Development Board

The Texas Water Development Board (TWDB), created in 1957, became responsible for long-range planning and water financing in 1985 through legislative action. Currently, the TWDB has the primary responsibility for water planning and for administering water financing for the State of Texas (TWC,1990a). These include water quality monitoring in coastal waterways, inflow assessments for embayments, overseeing the use of Federal funds for the Construction Grants Program, and coordination with the Texas Parks and Wildlife Department concerning studies and analyses used in decisions regarding the effects of water allocation on Texas' estuaries (David Brock, TWDB, personal communication).

3.5.1 Coastal Data System

The Texas Water Development Board collects and maintains data relating to water quality for the purpose of assessing trends and current conditions in estuarine systems along the Texas coast (David Brock, TWDB, personnel communication). These data are predominantly water quality oriented but include sediment analysis and aquatic organism tissue analysis. The program was originally a cooperative effort between the U.S. Geological Survey and the TWDB between 1967 and 1983. The Texas Water Commission involvement extended from 1984 until the end of routine monitoring in 1989. Data from the Coastal Data System is maintained on the Texas Water Commission mainframe computer and is accessed through the Texas Natural Resource Information System (TNRIS). The database includes data for all seven of the major bay systems located along the Texas Gulf Coast, including Galveston Bay.

Sampling stations in the study area are established along transects as shown in Figure 9. The transects are oriented perpendicular to the centerline of embayments. Sampling locations for the Galveston Bay system include Galveston Bay, Trinity Bay, East Bay, West Bay, Chocolate Bayou, Dickinson Bayou, Moses Bayou, and Clear Creek. Two additional sampling points are located approximately 3 miles into the Gulf of Mexico.

3.5.2 Segment Boundary Analysis

The Texas Department of Water Resources conducted an analysis of Galveston Bay segment boundaries based on physical characteristics and nutrient processes using historical data collected by the USGS between 1941 and 1976. The report was one in a series of reports on major Texas estuaries developed to analyze existing data for the purpose of water quality planning under Section 208 of PL 92-500. The report includes three sections. The first section presents an analysis of the appropriateness of existing bay segment boundaries for water quality planning purposes. The second section presents physical characteristics of Galveston Bay along with a summary of circulation and salinity patterns under average conditions of seasonal tidal amplitude, wind, and freshwater inflow. The third part of this report deals with nutrient processes taking place in the Bay including the effects of inflows on nutrient cycling and contributions of nutrients from deltaic marshes. Circulation and salinity patterns were simulated by TDWR using computer models calibrated from sampling efforts in the estuary. The results of the computer simulation suggested that West Bay and Trinity Bay segments are appropriate for current conditions. Because of the influence of Hanna Reef on circulation, the previous boundary between Galveston and East Bay was moved east of its previous location. Predictions made by salinity simulations resulted in the division of Galveston Bay into upper and lower segments, Segments 2421 and 2439, respectively. An analysis of net circulation patterns simulated by the tidal hydrodynamic model indicated that the circulation in Galveston Bay is dominated by movement of water along the Houston Ship Channel. The simulated circulation patterns in Trinity, East, and West Bays were predicted by the simulation to be dominated by internal circulation currents (TDWR, 1979).

3.5.3 Freshwater Inflow Information

The TDWR developed a series of reports for Texas bays and estuaries as mandated by Senate Bill 137 which called for comprehensive studies of the effects of freshwater inflows to the bays (TDWR, 1981). The Galveston Bay system study was completed by TDWR in 1981 and includes modeled circulation and salinity patterns for each month of the year. This 1981 study was also intended to supplement knowledge gained from the "Analysis of Bay Segment Boundaries, Physical Characteristics, and Nutrient Processes" the 1979 TDWR 208 study

referenced previously. Mathematical computer models calibrated with data collected from the bay were used to predict hydraulic conditions in the bay. Historical stream flow data was obtained from USGS continuous recording stream gaging stations. Salinity data continuously collected using in-place "sonde" meter devices was used to calibrate a model for predicting circulation patterns. Examples of net circulation and salinity patterns in the Bay estimated for the month of January are presented in Figures 10 and 11. Simulated net circulation patterns indicate boundaries occur at the Houston Ship Channel, midway across Trinity Bay, Chocolate Bayou, Clear Lake, and near the East Bay-Galveston Bay convergence. Modeled salinity concentration patterns suggest boundaries exist for Trinity Bay, East Bay, Dickinson Bay, and Chocolate Bayou. The report includes similar figures for each month which show similar patterns throughout most of the year (TDWR, 1981).

3.5.4 1989 Study of Circulation patterns in Galveston Bay

The TWDB has collected data from Galveston Bay in addition to that maintained in the Coastal Data system. The TWDB conducted an intensive study in May of 1989 for the purpose of assessing circulation patterns in Galveston Bay based on flows measured at the passes within the bay. At that time, current speed and direction data were collected at monitoring points located at major passes and inlets within the Bay system during two complete tide cycles (TWDB, 1989). This study was a joint effort between the TWDB, Texas Water Commission, Texas Parks and Wildlife Department, Tarrant County Water Control and Improvement District No. 1, and the U.S. Army Corps of Engineers. Since 1989, the TWDB has collected salinity data from five locations in the Bay using Datasonde meters which take readings every 1.5 hours. Information gathered from these sources was used by the TWDB to develop a two-dimensional model for the Galveston Bay system (Brock, 1990).

3.6 U.S. Environmental Protection Agency

The U.S. Environmental Protection Agency (EPA) has developed an independent segmentation scheme that includes both freshwater streams and tidal waters. The framework for this segmentation scheme was originally established whereby unique segment codes were established for waterways in ascending order from most downstream to upstream segments within each

hydrologic unit. A hydrologic unit is identified by a unique hydrologic unit code (HUC). This is a unique number that identifies a "geographic area representing part or all of a surface drainage basin or distinct hydrologic feature as delineated by the Office of Water Data Coordination on the State Hydrologic Unit maps" (Buckner, 1989). New codes are established as new waterbodies are added to the system. Only part of the Galveston Bay system has yet been segmented by the EPA as of this time although full coverage of the entire Texas coast will eventually be available (Parrish, 1991).

3.7 U. S. Fish and Wildlife Service

3.7.1 Threatened and Endangered Species

Species listed as either threatened and endangered for Chambers, Galveston, and Harris counties by the U.S. Fish and Wildlife Service (USFWS) appear in Table 3. There are several threatened and endangered reptiles, specifically sea turtles such as the loggerhead, green, leatherback, hawksbill, and Kemp's ridley, that occur within the bay itself. According to Kathy Nemec, USFWS Clear Lake City, sea turtles can range throughout Galveston Bay. These species require undisturbed shoreline for nesting purposes. However, there are no known sea turtle nesting locations around the bay. According to C.T. Fontaine with the NMFS in Galveston, the habitat used by sea turtles within Galveston Bay is not known. Most of the information about sea turtles utilizing Galveston Bay comes from the Headstart Program for the Kemp's ridley sea turtle and the Turtle Stranding Network (Fontaine, 1991). Kemp's ridley sea turtles that are released by the Headstart Program are tagged. The general public is very aware of this program so a great deal of information is received by NMFS when tagged sea turtles or wild sea turtles are observed. Information about stranded sea turtles or dead sea turtles that washed ashore is available from the Stranding Network (Fontaine, 1991).

TABLE 3

THREATENED AND ENDANGERED SPECIES FOR CHAMBERS, GALVESTON, AND HARRIS COUNTIES, U.S. FISH AND WILDLIFE SERVICES

Common Name	*Scientific Name*	*Status*
Chambers County Reptiles		
Loggerhead sea turtle	*Caretta caretta*	Threatened
Green sea turtle	*Chelonia mydas*	Threatened
Leatherback sea turtle	*Dermochelys coriacea*	Endangered
Hawksbill sea turtle	*Eretmochelys imbricata*	Endangered
Kemp's ridley sea turtle	*Lepidochelys kempii*	Endangered
Chambers County Birds		
Brown Pelican	*Pelecanus occidentalis*	Endangered
Piping Plover	*Charadrius melodus*	Threatened
Bald eagle (N)	*Haliaeetus leucocephalus*	Endangered
Arctic peregrine falcon	*Falco peregrinus tundrius*	Threatened
Galveston County Reptiles		
Loggerhead sea turtle	*Caretta caretta*	Threatened
Green sea turtle	*Chelonia mydas*	Threatened
Leatherback sea turtle	*Dertmochelys coriacea*	Endangered
Hawksbill sea turtle	*Eretmochelys imbricata*	Endangered
Kemp's ridley sea turtle	*Lepidochelys kempii*	Endangered
Galveston County Birds		
Brown pelican	*Pelecanus occidentalis*	Endangered
Piping plover (W)	*Charadrius melodus*	Threatened
Attwater's greater prairie-chicken (R)	*Tympanuchus cupido attwateri*	Endangered
Bald eagle	*Haliaeetus leucocephalus*	Endangered
Arctic peregrine falcon	*Falco peregrinus tundrius*	Threatened
Harris County Plants		
Prairie dawn	*Hymenoxys texana*	Endangered
Harris County Amphibians		
Houston toad (H)	*Bufo houstonensis*	Endangered
Harris County Birds		
Bald eagle (N)	*Haliaeetus leucocephalus*	Endangered
Arctic peregrine falcon	*Falco peregrinus tundrius*	Threatened
Red-cockaded woodpecker	*Picoides borealis*	Endangered

The USFWS lists several birds as threatened and endangered in Chambers, Galveston, and Harris counties (Table 3). Brown pelicans are known to occur throughout the Texas coast (Figure 12) and are listed as endangered in Chambers and Galveston counties. Two roosting sites but no nesting sites are known for Galveston Bay according to the 1990 Colonial Water Bird Survey (TPWD, 1990).

The piping plover, which is listed as threatened in Chambers and Galveston counties, is a winter resident of the Texas coast. However, it does not nest in Texas. Winter concentration sites within Galveston Bay for the piping plover are located in Figure 13.

The bald eagle is listed as endangered in Chambers, Galveston, and Harris counties. Bald eagle nesting sites are known to occur within Chambers, Galveston, and Harris counties. However, specific nesting sites for the bald eagle did not appear on maps obtained from the USFWS.

The Arctic peregrine falcon is listed as threatened in the counties surrounding Galveston Bay. However, according to Ms. Kathy Nemec, USFWS, it is known only as a migrant, and no important use sites are known within Chambers, Galveston, or Harris counties.

The Attwater's greater prairie chicken is listed as endangered in Galveston County by the USFWS. Its known area of distribution in Galveston County appears in Figure 14.

The only amphibian listed as endangered in the three-county area of concern is the Houston toad. It occurred historically in Harris County, but its current existing distribution does not include Harris County.

Prairie dawn is the only plant species listed as endangered in the three-county area of concern by the USFWS. It is listed as endangered in Harris County.

3.8 National Wildlife Refuges

The Anahuac National Wildlife Refuge includes 24,000 acres along the north shore of East Bay approximately 16 miles southeast of the town of Anahuac. The refuge provides wintering habitat for large concentrations of geese and other waterfowl. Species of special interest found here include the endangered bald eagle and perigrine falcon, the alligator, mottled duck, wood stork, and least tern (USFWS, 1988).

The Brazoria National Wildlife Refuge includes approximately 12,000 acres along the west shore of Bastrop Bay, Christian Bay, and Drum Bay. The refuge has been set aside as a waterfowl wintering area. The Brazoria Refuge is within the Freeport Christmas bird count circle which frequently achieves the highest number of species seen in a 24-hour period. Fishing and waterfowl hunting is permitted in season but are restricted to boat access only (USFWS, 1988).

3.9 U.S. Army Corps of Engineers

Locations of current dredge disposal areas permitted by the U.S. Army Corps of Engineers were provided on maps for the Galveston Bay area through the Corps District Office in Galveston (USCOE, 1990). Generally, these disposal sites are located along the intracoastal waterway from east of Chocolate Bay to the mouth of East Bay Bayou, in the north section of Galveston Bay, off the eastern shore near Texas City, at Pelican Island, and along the eastern end of Galveston Island.

These spoil sites can alter circulation patterns in the Bay due to the alteration of the Bay bottom contours and the shallow nature of these waters. Circulation patterns altered by channels would be further enhanced by the presence of long narrow spoil areas like those located along the intracoastal waterway. The spoil sites in the northern end of Galveston Bay, located to the east of the Houston Ship Channel, should enhance the channeling effect on inflows from the San Jacinto River already created by the ship channel and thereby increase the boundary effect along the channel. As discussed in Section 3.4 of this report, spoil area location information that was incorporated into the GIS system was obtained through the General Land Office. Dredge spoil areas inside the study area are shown in Figure 8.

3.10 National Marine Fisheries Services

Bessette (1985) reported that the NMFS divided the Galveston Bay system into five areas. These areas were Upper and Lower Galveston Bay, Trinity Bay, East Bay, and West Bay. The NMFS and predecessor agencies have used these subdivisions since 1961 (U.S. Department of the Interior, et. al., 1962). These areas were further subdivided which resulted in the segmentation system observed in Figure 15. This segmentation system was developed to report commercial fishery statistics. The subdivisions within five areas were arbitrarily selected (Zoula Zein-Eldin, personal communication). After 1975, all subdivisions in Galveston Bay were discontinued. Commercial fishery statistics were reported for inshore (Galveston Bay) and offshore (Gulf of Mexico) areas except for special surveys where the pre-1975 subdivisions were used (Zoula Zein-Eldin, personal communication).

3.11 National Oceanographic and Atmospheric Administration

The Coastal Ocean Management Planning and Assessment System (COMPAS) is being developed within the Strategic Assessment Program of NOAA. The purpose of COMPAS in Texas is to convert existing estuarine-related natural resource data into a common format that can be visually displayed to assist in management decisions regarding impacts to natural resources. Data currently being used for COMPAS include but are not limited to the following:

- Water Rights
- U.S. Geological Survey Freshwater Gaging Stations
- Texas Water Commission Stream Monitoring Network Stations with some Water Quality Data
- Land Use Data
- Habitat Types (e.g., bottom sediment types, saltmarsh, freshwater marsh, forested lands, tidal flats, etc.)
- Recreational Sites
- Point and Nonpoint Source Pollutant Loadings
- Physical and Hydrological Characteristics
- Highways

- Shellfish Locations
- Housing and Population
- Coastal Tracts
- NPDES Permitted Facilities
- NOAA National Status and Trends Data
- Finfish and Shellfish Distribution Data

A simple two-dimensional model will also be developed that will be used to estimate pollutant concentration isobars given certain flow regimes and point source locations. The Marine Resources Module will include distribution profiles for five life stages of 40 species of freshwater and saltwater finfish and shellfish. Distribution profiles within three zones (i.e., 0 to 0.5 parts per thousand (ppt), 0.5 to 25 ppt, and greater than 25 ppt). The predicted completion date for COMPAS in Texas is February 1992.

NOAA navigational charts at a scale of 1:25,000 were utilized in developing the shoreline boundaries and embayment features such as ship channels, markers, and bay bottom obstructions. Hydrography and topography for these maps are developed by the National Ocean Service, Charting and Geodetic Services with additional data provided by the U.S. Army Corps of Engineers, U.S. Geological Survey, and the U.S. Coast Guard (NOAA,1990). Figure 16 is a bathymetric map of the area developed from the NOAA charts.

3.12 Texas Water Quality Board/ University of Texas Marine Science Institute

The Galveston Bay Project was a comprehensive program implemented to study specific features of the Galveston Bay system including its water sources and industrial and urban impacts. One of the components of the study was the "Toxicity Studies of Galveston Bay Project" conducted by the University of Texas Marine Science Institute (UTMSI) located in Port Aransas and contracted through the Texas Water Quality Board to conduct toxicity studies on living communities in the Bay and its primary productivity. The scope of the study was to "determine the water quality of relatively stable salinity/temperature areas representing five general locations in the Galveston Bay system" (UTMSI, 1973). These five sampling locations, shown in Figure 17, were established in the Bay within described limits of temperature and salinity to more

each data collection project associated with Galveston Bay as well as sources through which these can be obtained. The CRWR developed segmentation for Galveston Bay and the Houston Ship Channel based on hydrographic boundaries for use in the GBNEP status and trends project (Ward,1991). The process involved three systems: Galveston Bay, the Houston Ship Channel, and the proximal Gulf of Mexico. Under the chosen scheme, Galveston Bay includes separate segments for the Texas City Ship Channel and the Houston Ship Channel due to the "peculiar hydrodynamics of salinity intrusion and increased tidal response dictated by the deeper water, and also due to the effect of dredge disposal areas on the lateral boundaries of these channels". Areas where the return waters of major power plants enter the Bay are segmented separately to isolate the resulting thermal plume. Segment boundaries also occur at the mouths of East Bay due to Hanna Reef, Trinity Bay, Tabbs Bay, Clear Lake, Dickinson Bay, and Chocolate Bay. The inland portion of the Houston Ship Channel defines a separate segment while all major inlets entering it are also delineated. Trinity Bay segments are oriented longitudinally to track the plume of runoff from the Trinity River. Hanna Reef, Carancahua Reef, and the mid-Bay reef/Red Fish Bar complexes define physical boundaries in the Bay. Whenever possible, the boundaries of the hydrographic segments defined in this study were made to coincide with the larger Texas Water Commission segments in order to simplify the aggregation process. The final segmentation scheme developed by CRWR is shown in Figure 22 through 24.

3.13.2 Bureau of Economic Geology

The Bureau of Economic Geology (BEG) developed its submerged lands series of atlases for the Bay systems of Texas in order to better define natural resource boundaries along the Texas coast. The Submerged Lands of Texas Project is based primarily on an intensive sampling program in which approximately 6,700 surficial bottom samples were collected at regularly-spaced intervals across the submerged lands (White, 1985). This information is intended for utilization by State, Federal, regional, and local agencies and for private businesses and individuals. The atlas on the Galveston-Houston area is the second in a series of seven publications focusing on the submerged lands and coastal wetlands of Texas from the Rio Grande to Sabine Lake. The series provide an extensive spatial data base on sediment texture, sediment geochemistry, benthic macroinvertebrates, and associated wetlands. Maps are included with each series publication which indicate the locations of homogeneous deposits of these resources.

"Textural analyses" of sediments by BEG "included quantitative determination of the gravel, sand, and mud fractions in each sample followed by more detailed textural analysis of the sand and mud fractions. Size distribution in the sand fraction was determined with a rapid sediment analyzer and in the mud (silt and clay) fraction with a Coulter Counter (Shideler, 1976)." Sediment texture maps showing gravel, sand and mud distribution are shown in Figure 25 and sand, silt, and clay distributions are shown in Figure 26.

Geochemistry data developed by the BEG and presented in White, (1985) were obtained from the sediment sampling efforts of BEG during 1976 and 1977. "Geochemical data on submerged lands consist of analyses of whole sediment samples to determine the concentration of total organic carbon (TOC) and a spectrum of major and trace elements. More than 6,500 samples were analyzed for TOC by staff at the Bureau's Mineral Studies Laboratory, using a wet-combustion technique (Jackson, 1958). Approximately 3,800 samples were analyzed for trace and major element concentrations. The U.S. Geological Survey performed most of these latter analyses using an emission spectrograph and a computerized system of spectral analysis (Dorrzapf, 1973), which provides semiquantitative results (relative standard deviation for each reported concentration being plus 50 percent and minus 33 percent) (White, 1985).

The distribution of wetlands from adjacent areas was interpreted and delineated by the BEG using National Aeronautics and Space Administration (NASA) stereoscopic, color-infrared (CIR) positive transparencies taken in 1979, at a scale of approximately 1:66,000. Wetlands found in Galveston Bay border submerged lands and occur in some inland areas. Wetland classification in these efforts was based primarily on vegetation and general moisture and salinity conditions. In the Galveston-Houston area, 19 map units including three marsh categories were used by the BEG to delineate wetlands.

3.14 Texas A&M University

A compilation of information sources pertaining to studies involving the marine environment and associated industry in Galveston Bay is available through the Sea Grant Program at Texas A&M University in College Station. Information categories available through this source include marine fishing, mariculture operations, oceanography, environmental quality, marine education,

marine business, marine economics, coastal and ocean engineering, marine transportation, and marine recreation (TAMU, 1988). Information resulting from projects within the Sea Grant Program are made available to the public by the Marine Information Service within the Sea Grant Program.

3.15 Houston-Galveston Area Council

Coastal preserves were created at Armand Bayou and Christmas Bayou near Galveston Bay under the existing joint Texas General Land Office (GLO) and Texas Parks and Wildlife Department (TPWD) Coastal Preserves Program. Coastal preserves are established in order to protect areas of unique environmental characteristics. Armand Bayou (TWC Segment 1113) is located between the City of Houston and Clear Lake. Christmas Bay (TWC Segment 2434) is on the western extent of West Bay (HGAC, 1991). The administrative boundaries of both are defined as the area located within each respective watershed that is also below the mean high tide line (MacRae,1991). Both preserves are composed entirely of State-owned lands.

3.16 City and County Jurisdictional Areas

The study area is comprised of four counties: Harris County, Brazoria County, Galveston County, and Chambers County. The county boundaries within the study area are shown on Figure 27. These were obtained from the State Department of Highways and Public Transportation (SDHPT, 1988). All of Trinity Bay and the bulk of upper Galveston Bay are within Chambers County. The Chambers/Harris county line forms a boundary across the northern edge of Galveston Bay from the southeastern corner of the city limits of the City of Morgans Point, separating Galveston Bay from the lower end of the Houston Ship Channel, to the northern end of Atkinson Island to the northern side of the mouth of Ash Lake, separating Galveston Bay and Tabbs Bay.

Harris County encloses the entire Houston Ship Channel, Buffalo Bayou Tidal, San Jacinto River Tidal, Tabbs Bay, San Jacinto Bay, Black Duck Bay, Scott Bay, and Burnett Bay. The Harris/Galveston county line forms a boundary that divides Clear Lake approximately down the middle of the bay and continues upstream to Clear Creek which forms the county line.

Galveston County encloses the bulk of lower Galveston Bay, all of East Bay, and most of West Bay, Dickinson Bay, Moses Lake, and Dollar Bay. The Galveston/Chambers county line forms an approximate boundary between upper and lower Galveston Bay from Eagle Point to just north of Smith Point.

Brazoria County includes the far western end of West Bay, Chocolate Bay, Bastrop Bay, Christmas Bay, and Drum Bay. The Brazoria/Galveston county line forms a boundary across the western end of West Bay from a point southwest of Carancahua Point diagonally across West Bay to the center of San Luis Pass.

Generally, city boundaries within the study area tend to follow the shoreline. However, in some cases, city boundaries do extend into parts of the Galveston Bay system. Also shown in Figure 27 are city boundaries that extend into and encompass parts of the Galveston Bay system.

The City of Houston corporate boundaries are drawn to include the Houston Ship Channel/San Jacinto River down to a point just north of the Baytown Tunnel and south of Alexander Island where they abut the corporate boundaries of La Porte and Baytown. The Baytown corporate boundary includes Goose Creek and forms a boundary separating it from the San Jacinto River. The La Porte corporate boundary encompasses most of Lower San Jacinto Bay, the southern portion of Upper San Jacinto Bay, and most of Santa Anna Bayou.

The city limits of the small town of Shoreacres extends approximately one-half mile into Galveston Bay for a distance of approximately one-quarter mile. The Seabrook city limits extend approximately 0.6 miles into upper Galveston Bay along approximately four miles of bay frontage. In addition, the city limits of Seabrook encompass parts of Taylor Lake and Clear Lake. The city limits of Pasadena encompasses most of Armand Bayou.

Nassau Bay city limits enclose a small part of Clear Lake, while the city limits of League City enclose a large portion of Clear Lake. Near the confluence of Clear lake with Galveston Bay, the community of Clear Lake Shores encloses a small part of Clear Lake.

The City of Texas City has a rather complex corporate boundary that encloses most of lower Dickinson Bayou and Dickinson Bay, all of Moses Lake and Dollar Bay, and parts of lower Galveston Bay. The Texas City corporate boundary is drawn to include the Texas City Dike and a zone of Galveston Bay on either side and most of the Texas City Ship Channel. The boundary of the Village of Tiki Island is a rectangle of approximately two square miles that includes portions of Jones Bay and West Bay.

The corporate limits of the City of Galveston includes a large portion of West Bay, part of lower Galveston Bay, part of Bolivar Roads, and a considerable area of the Gulf of Mexico. Within the corporate boundaries of Galveston are the Corporate boundaries of Jamaica Beach which include a small portion of West Bay.

Galveston Bay National Estuary Program

SEE FIGURE 4 SHT. 2 OF 2 FOR EXISTING HOUSTON SHIP CHANNEL SEGMENTATION.

SCALE: 1:250000

0 1 2 3 4 5 6 7 8 9 10 KILOMETERS

0 1 2 3 4 5 6 MILES

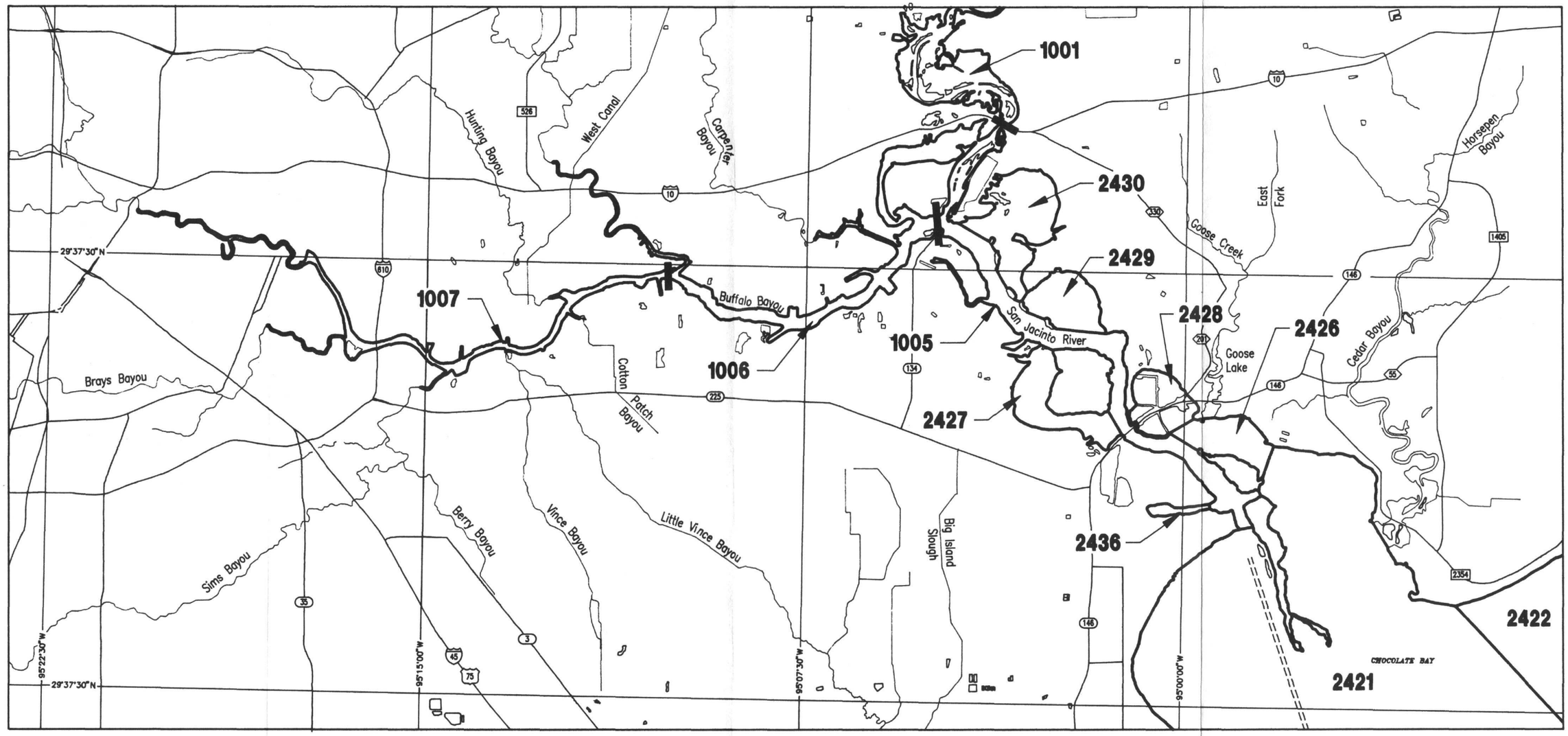
2430
2429
2427
2428
2436
2438
1113
1101
2425
2422
2421
1103
2431
2431
2437
2439
2423
1107
1105
2432
CHOCOLATE BAY
2424
2435
2433
2434
WEST BAY
TRINITY BAY
GALVESTON BAY
EAST BAY
GULF OF MEXICO
0901
1005
Lake Anahuac
Clear Lake
Moses Lake
Bickinson Bay
BOLIVAR ROADS
95°15'00"W
95°07'30"W
95°00'00"W
94°52'30"W
94°45'00"W
29°52'30"N
29°37'30"N
29°45'00"N
29°30'00"N
29°22'30"N
29°07'30"N
29°15'00"N

FIGURE - 3
EXISTING TEXAS WATER COMMISSION SEGMENTS
GALVESTON EMBAYMENTS
SHEET 1 OF 2

JONES AND NEUSE, INC.
Environmental and Engineering Services

Galveston Bay National Estuary Program

SEE FIGURE 3 SHT. 1 OF 2 FOR
GALVESTON BAY AREA SEGMENTATION.



SCALE: 1:126720

0 1 2 3 4 5 6 7 KILOMETERS

0 1 2 3 4 MILES

FIGURE – 4
EXISTING TEXAS WATER COMMISSION SEGMENTS
HOUSTON SHIP CHANNEL
SHEET 2 OF 2

JONES AND NEUSE, INC.
Environmental and Engineering Services

Galveston Bay National Estuary Program

SCALE: 1:250000

0 1 2 3 4 5 6 7 8 9 10 KILOMETERS

0 1 2 3 4 5 6 MILES

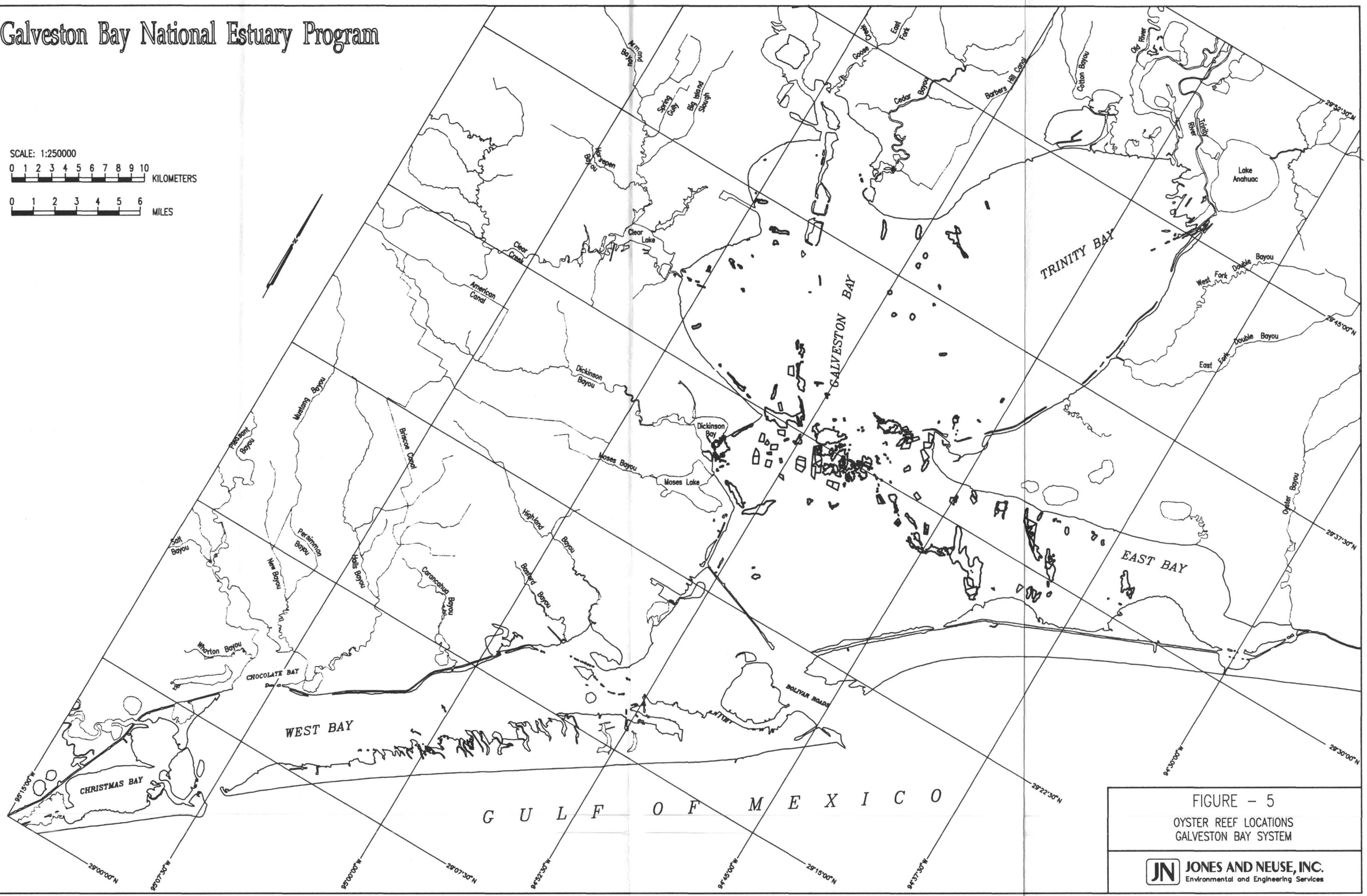


FIGURE – 5

OYSTER REEF LOCATIONS
GALVESTON BAY SYSTEM

JONES AND NEUSE, INC.
Environmental and Engineering Services

Galveston Bay National Estuary Program

LEGEND

- Approved areas
- Conditionally approved areas
- Polluted areas

1 Dollar Reef Markers
2 Navigational Marker "4"
3 Eagle Point Shellfish Marker
4 Sun Oil Platform #3 Land Tract 307
5 Tenneco Platform Land Tract 259
6 Navigational Marker "72"
7 Navigational Marker "68"
8 Navigational Marker "5"
9 Little Yellow Separator
10 Sunoco Separator #1 (Old Yellow)
11 Humble Separator C-1
12 Separator F-2 Land Tract 22-23B
13 Production Platform C-44 Land Tract 12-B
14 Navigational Marker "14"
15 Navigational Marker "2"
16 White Shell Island
17 Inshore Abandoned Platform (Picnic Table)
18 Rea Production Platform Land Tract 137
19 Northeast Corner Lease 413
20 Little Baytown Pier
21 Tide Guage Piling
22 Navigational Marker "53"
23 Navigational Marker "61"
24 Navigational Marker "15"
25 Bolivar Lighthouse

SCALE: 1:250000

0 1 2 3 4 5 6 7 8 9 10 KILOMETERS

0 1 2 3 4 5 6 MILES

AREA 1

AREA 2

AREA 3

TRINITY BAY

EAST BAY

GALVESTON BAY

CHOCOLATE BAY

WEST BAY

CHRISTMAS BAY

G U L F O F M E X I C O

Armand Bayou
Spring Gully
Big Island Slough
Clear Creek
American Canal
Clear Lake
Dickinson Bayou
Mustang Bayou
Pleasant Bayou
Bricose Canal
Moses Bayou
Moses Lake
Dickinson Bay
Goose Creek
East Fork
Cedar Bayou
Barbers Hill Canal
Cotton Bayou
Old River
Trinity River
Lake Anahuac
West Fork Double Bayou
East Fork Double Bayou
Oyster Bayou
Salt Bayou
New Bayou
Persimmon Bayou
Halls Bayou
Highland Bayou
Caramcahua Bayou
Bastrop Bayou
Whorton Bayou

29°30'00"N
29°37'30"N
29°45'00"N
29°22'30"N
29°15'00"N
29°07'30"N
29°00'00"N
94°30'00"W
94°37'30"W
94°45'00"W
94°52'30"W
95°00'00"W
95°07'30"W
95°15'00"W

FIGURE - 6

CLASSIFICATION OF SHELLFISH HARVESTING AREAS
GALVESTON BAY AREA

JONES AND NEUSE, INC.
Environmental and Engineering Services

Galveston Bay National Estuary Program

SCALE: 1:250000

0 1 2 3 4 5 6 7 8 9 10 KILOMETERS

0 1 2 3 4 5 6 MILES

TRINITY BAY

EAST BAY

GALVESTON BAY

WEST BAY

CHOCOLATE BAY

CHRISTMAS BAY

G U L F O F M E X I C O

Armand Bayou
Spring Gully
Big Island Slough
Goose Creek
East Fork
Cedar Bayou
Barbers Hill Canal
Cotton Bayou
Old River
Trinity River
Lake Anahuac
Horsepen Bayou
Clear Lake
Clear Creek
American Canal
West Fork Double Bayou
East Fork Double Bayou
Oyster Bayou
Dickinson Bayou
Dickinson Bay
Moses Bayou
Moses Lake
Mustang Bayou
Prairie Santa Bayou
Bricole Canal
Salt Bayou
Persimmon Bayou
Net Bayou
Halls Bayou
Highland Bayou
Bastrop Bayou
Carancahua Bayou
Whorton Bayou
Pelican Islands

29°30'30"N
29°15'00"N
29°30'00"N
29°22'30"N
29°37'30"N
29°07'30"N
29°00'00"N
95°15'00"W
95°00'00"W
94°52'30"W
94°45'00"W
94°37'30"W
94°30'00"W

FIGURE – 7

GENERAL LAND OFFICE TRACTS
GALVESTON BAY SYSTEM

JONES AND NEUSE, INC.
Environmental and Engineering Services

Galveston Bay National Estuary Program

SCALE: 1:250000

0 1 2 3 4 5 6 7 8 9 10 KILOMETERS

0 1 2 3 4 5 6 MILES

LEGEND

Dredge Spoil Areas

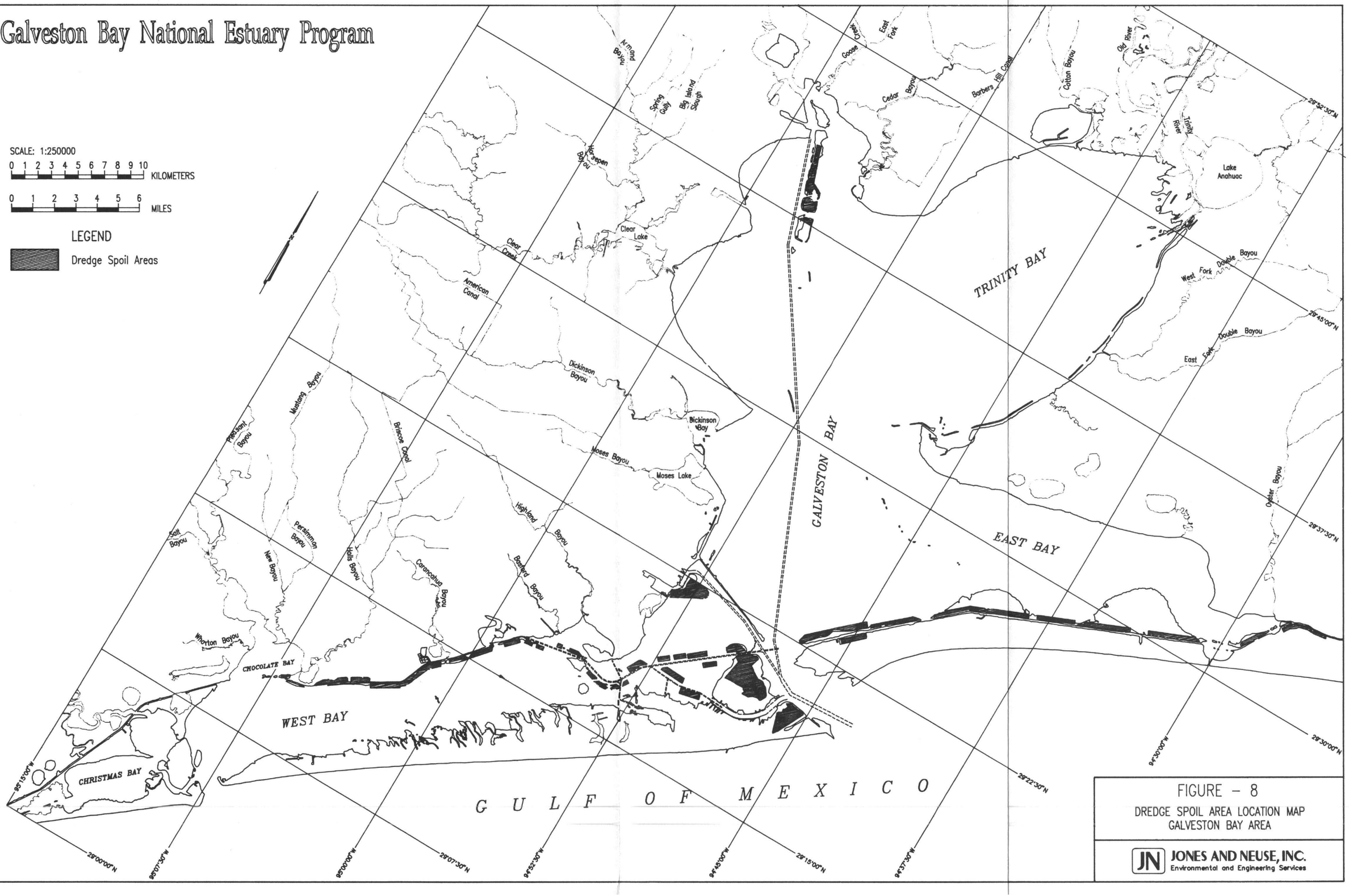
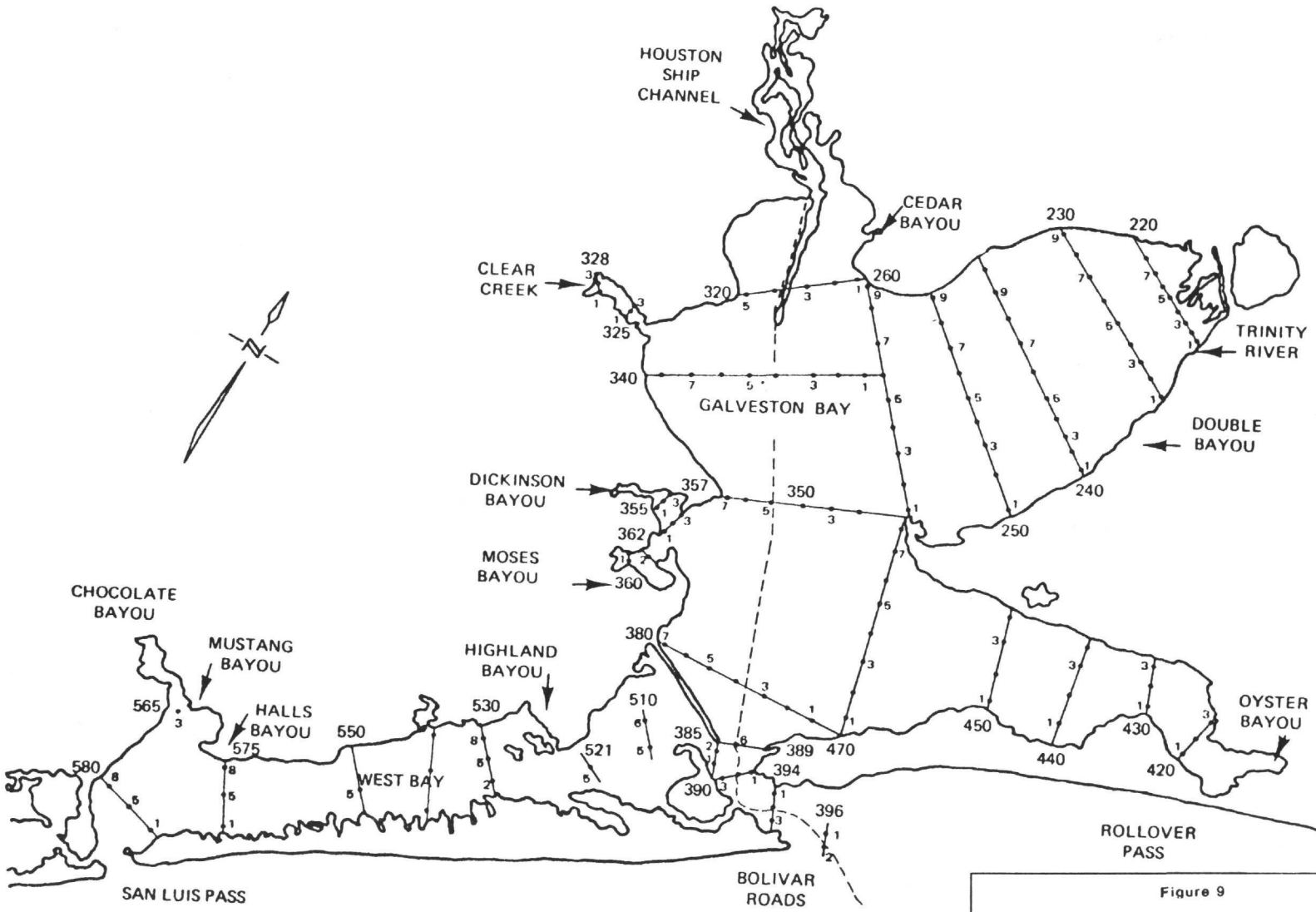


FIGURE – 8

DREDGE SPOIL AREA LOCATION MAP
GALVESTON BAY AREA

JONES AND NEUSE, INC.
Environmental and Engineering Services



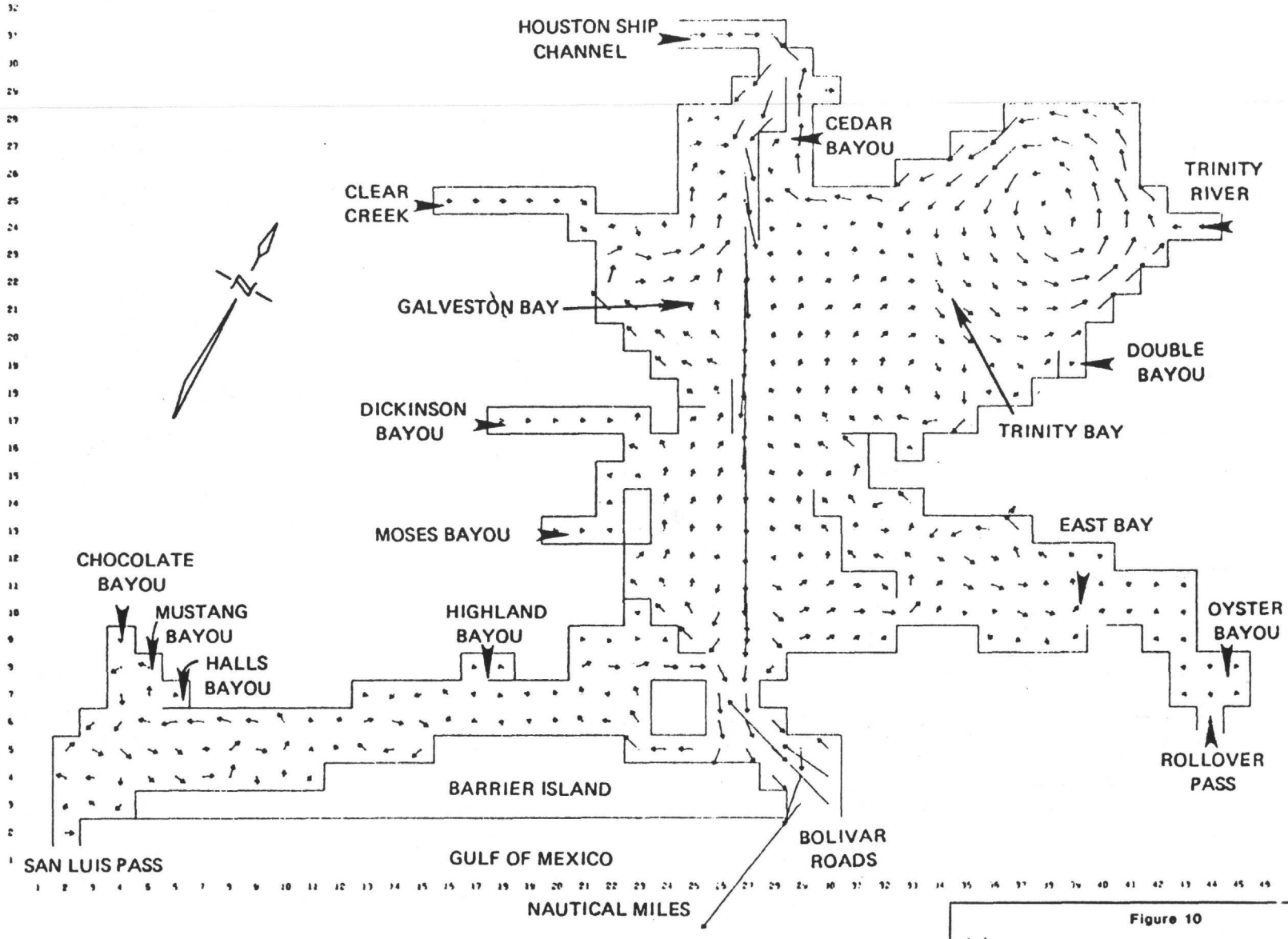
From: TDWR, 1979, "Trinity-San Jacinto Estuary: An Analysis of Bay Segment Boundaries, Physical Characteristics, and Nutrient Processes"

Figure 9

Coastal Data System Sampling Point Locations

Galveston Bay System

JONES AND NEUSE, INC.
Environmental and Engineering Services



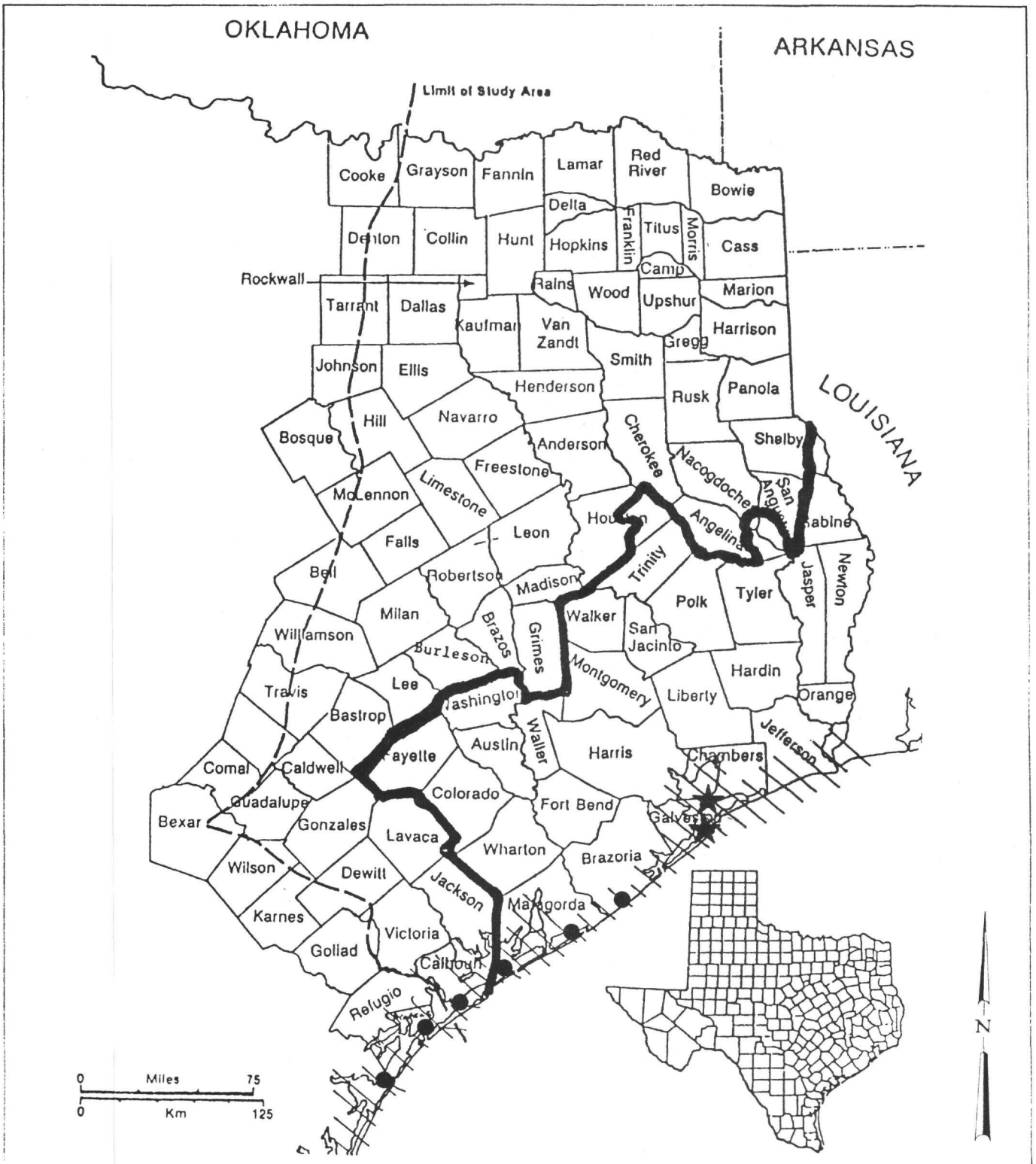
From: TDWR, 1981, "Trinity-San Jacinto Estuary: A Study of the Influence of Freshwater Inflows"

Figure 10

Net Circulation Patterns Developed from TDWR Study

Galveston Bay System

JONES AND NEUSE, INC.
Environmental and Engineering Services



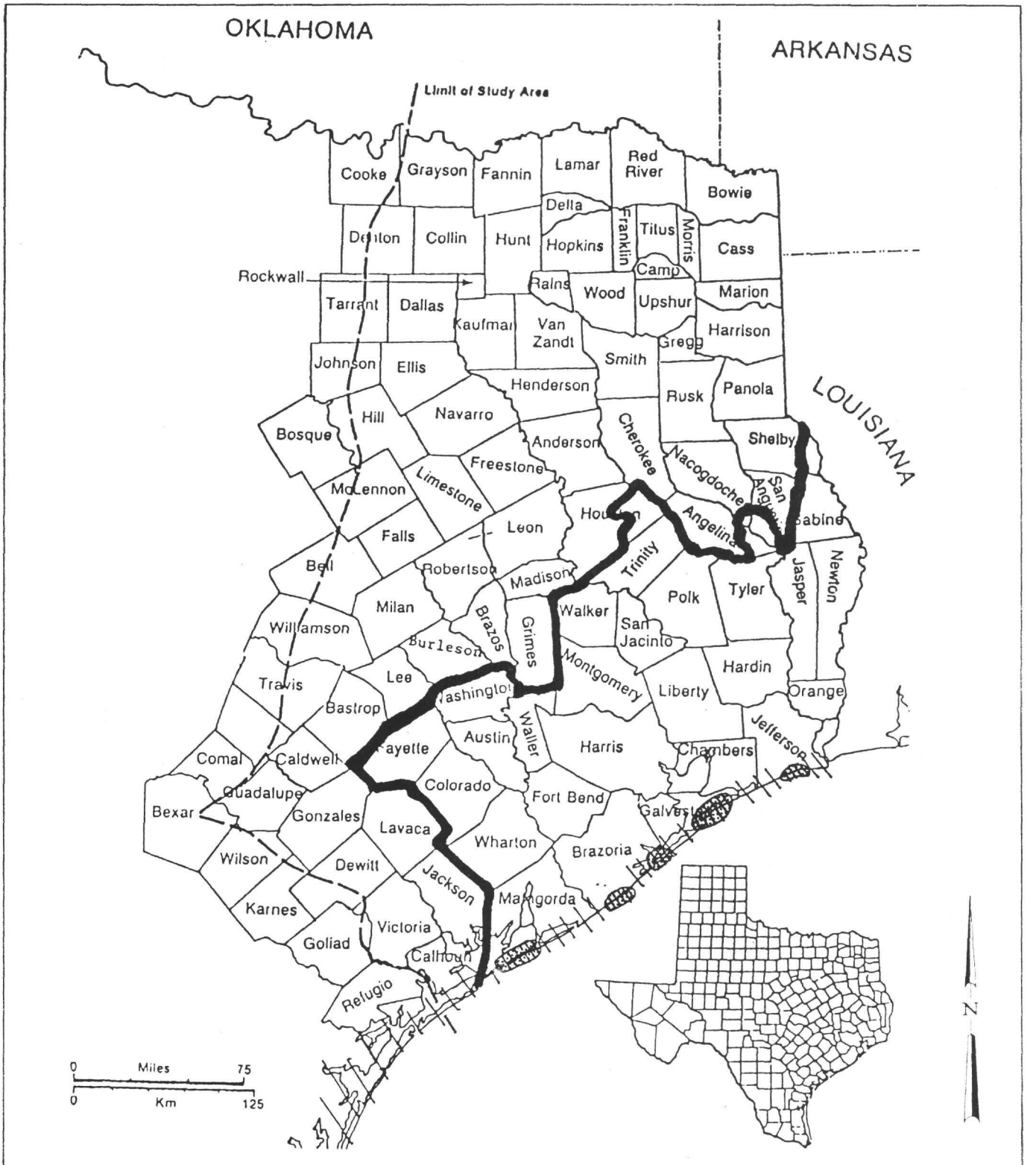
JN 01-0896-01.1

FIGURE 12

BROWN PELICAN DISTRIBUTION ON UPPER COAST, USFWS, MAY 1, 1991

GALVESTON BAY NATIONAL-GALVESTON BAY, TEXAS

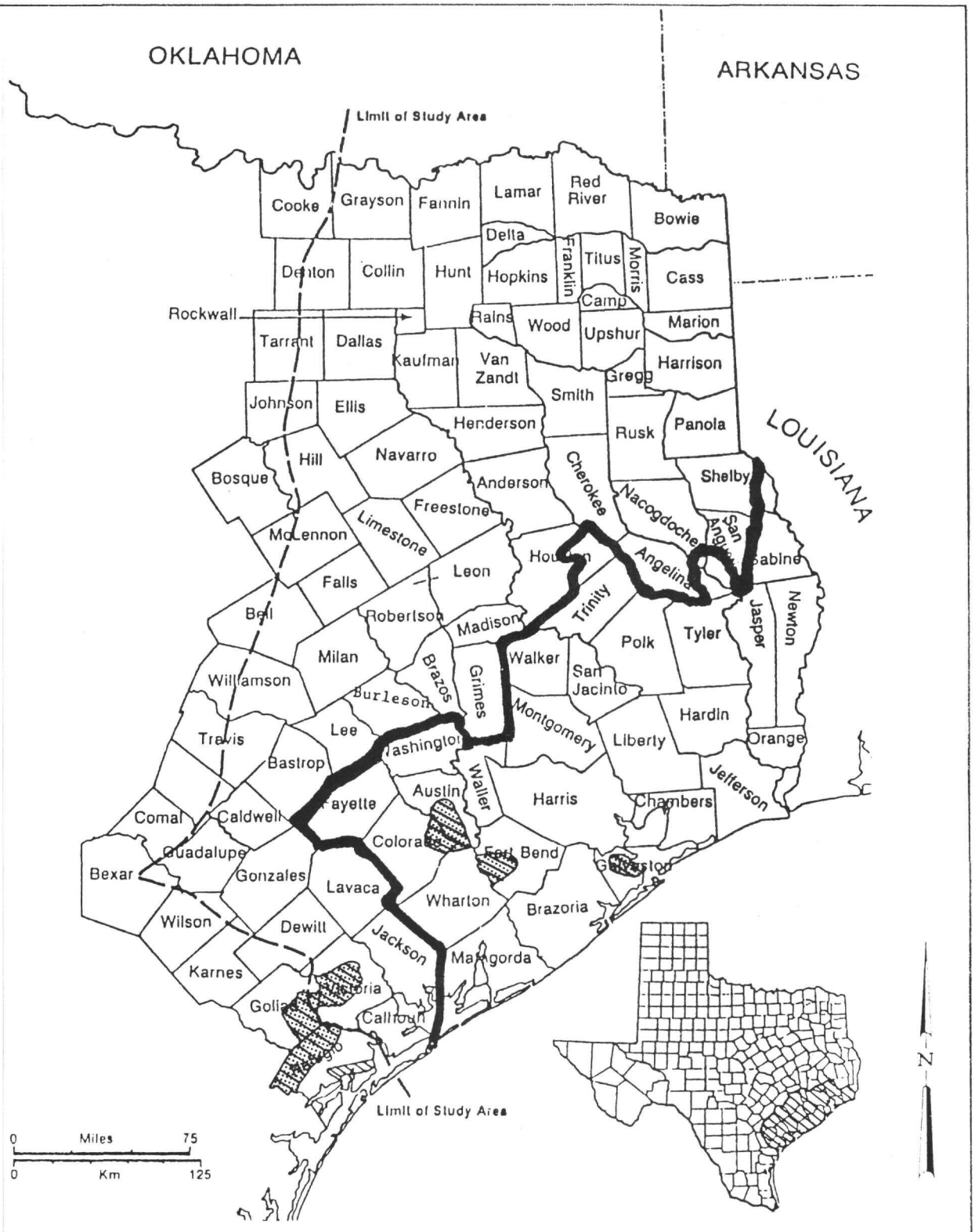
JONES AND NEUSE, INC.
Environmental and Engineering Services



JN 01-0896-01.1

FIGURE 13
PIPING PLOVER WINTER CONCENTRATION SITES ON UPPER TEXAS COAST, USFWS, MAY 1, 1991
GALVESTON BAY NATIONAL-GALVESTON BAY, TEXAS

JONES AND NEUSE, INC.
Environmental and Engineering Services



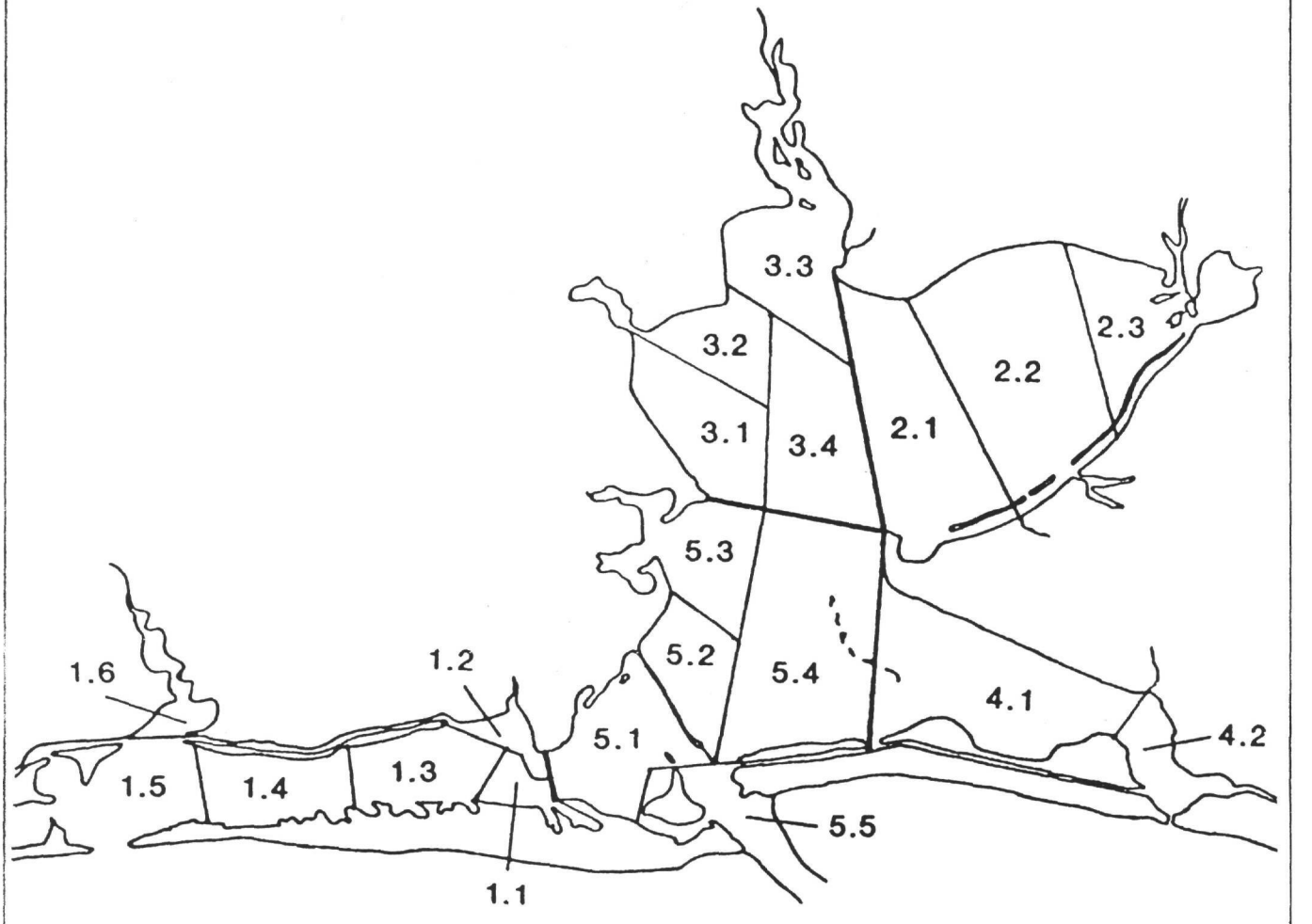
JN 01-0896-01.1

FIGURE 14

ATTWATER'S PRAIRIE CHICKEN DISTRIBUTION ON UPPER TEXAS COAST,USFWS, MAY1, 1991

GALVESTON BAY NATIONAL-GALVESTON BAY, TEXAS

JONES AND NEUSE, INC.
Environmental and Engineering Services



JN 01-0896-01.1

FIGURE 15

SUBDIVISIONS OF GALVESTON BAY USED BY THE NMFS

GALVESTON BAY NATIONAL-GALVESTON BAY, TEXAS

JONES AND NEUSE, INC.
Environmental and Engineering Services

Galveston Bay National Estuary Program

SCALE: 1:250000

0 1 2 3 4 5 6 7 8 9 10 KILOMETERS

0 1 2 3 4 5 6 MILES

TRINITY BAY

EAST BAY

GALVESTON BAY

WEST BAY

CHOCOLATE BAY

CHRISTMAS BAY

G U L F O F M E X I C O

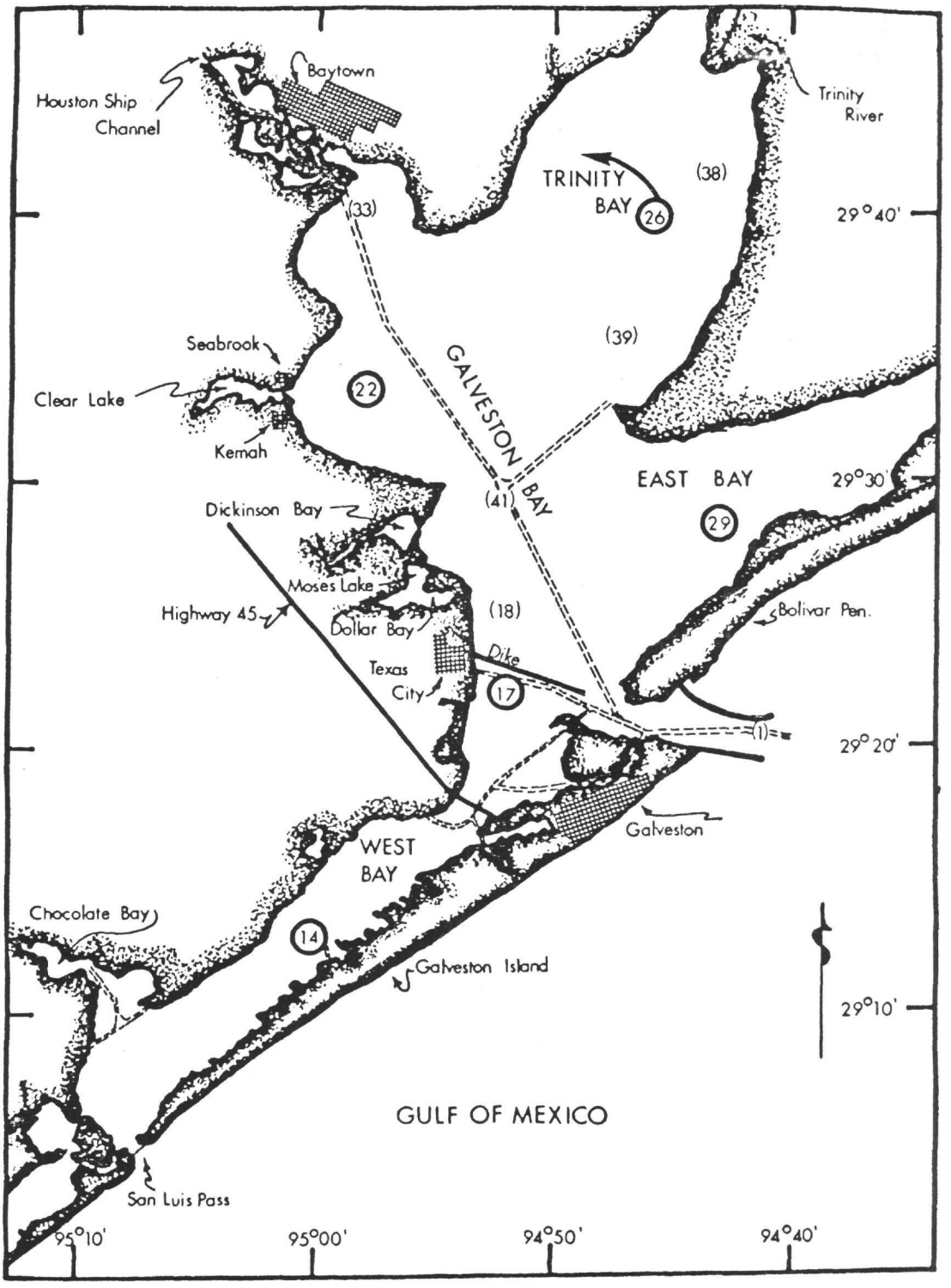
Armour Bayou
Spring Gully
Big Island Slough
Goose Creek
East Fork
Cedar Bayou
Barbers Hill Canal
Cotton Bayou
Old River
Trinity River
Lake Anahuac
Hog Pen Bayou
Clear Lake
Clear Creek
American Canal
West Fork Double Bayou
Double Bayou
East Fork Double Bayou
Oyster Bayou
Dickinson Bayou
Dickinson Bay
Mustang Bayou
Pleasant Bayou
Bricole Canal
Moses Bayou
Moses Lake
Highland Bayou
Bastrop Bayou
Salt Bayou
Persimmon Bayou
New Bayou
Halls Bayou
Caroncahua Bayou
Whorton Bayou

29°30'30"N
29°45'00"N
29°37'30"N
29°22'30"N
29°15'00"N
29°07'30"N
29°00'00"N
94°37'30"W
94°45'00"W
94°52'30"W
95°00'00"W
95°07'30"W
95°15'00"W

Source: The University of Texas at Austin
Bureau of Economic Geology

FIGURE – 16
BATHYMETRIC MAP
GALVESTON BAY AREA

JONES AND NEUSE, INC.
Environmental and Engineering Services



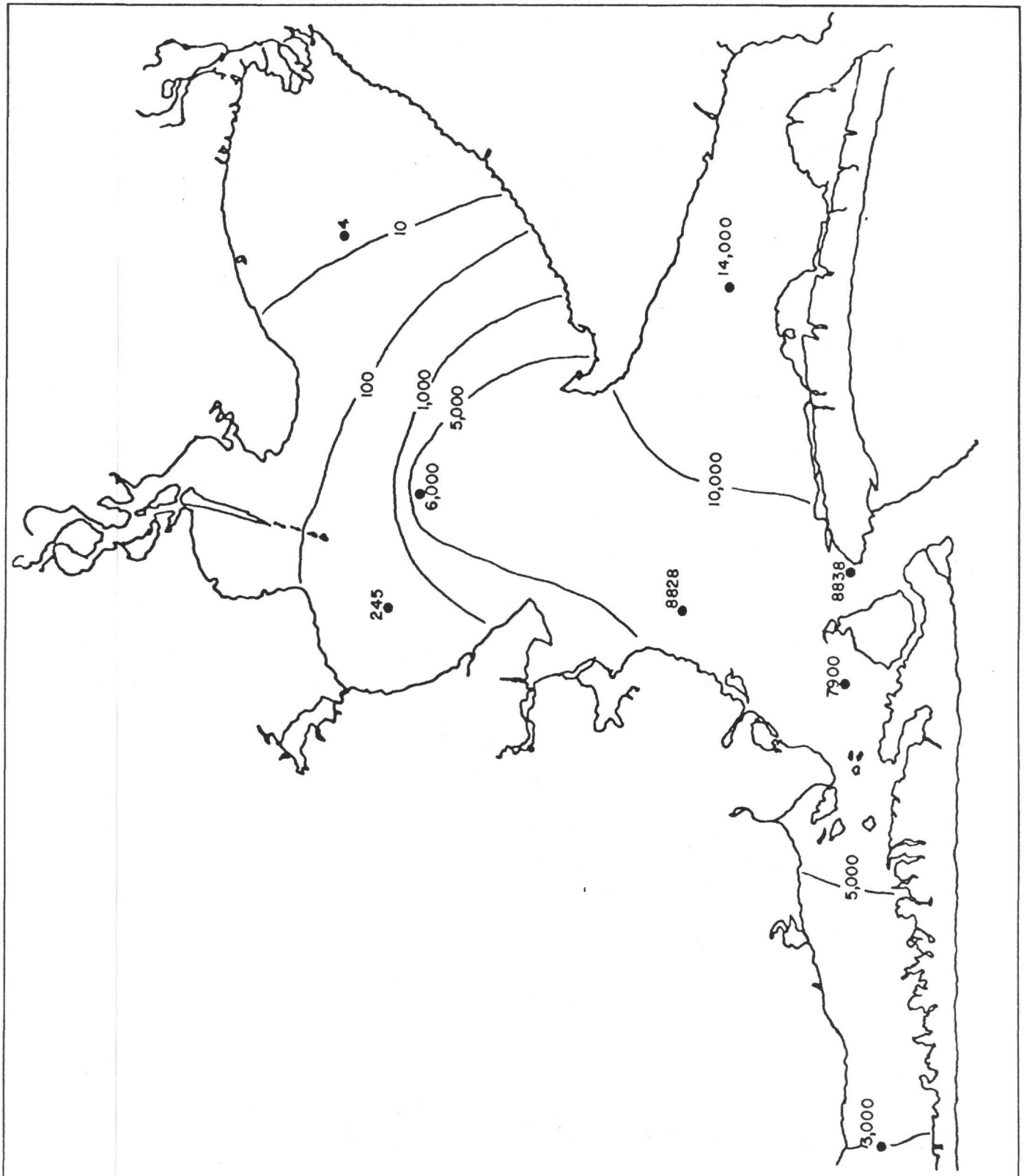
From: UTMSI, 1973, "Toxicity Studies of Galveston Bay Project"

Figure 17

TWQB/UTMSI Sampling Station Locations

Galveston Bay System

JONES AND NEUSE, INC.
Environmental and Engineering Services



From: UTMSI, 1973, "Toxicity Studies of Galveston Bay Project"

* Contours produced from data obtained from Copeland, 1970

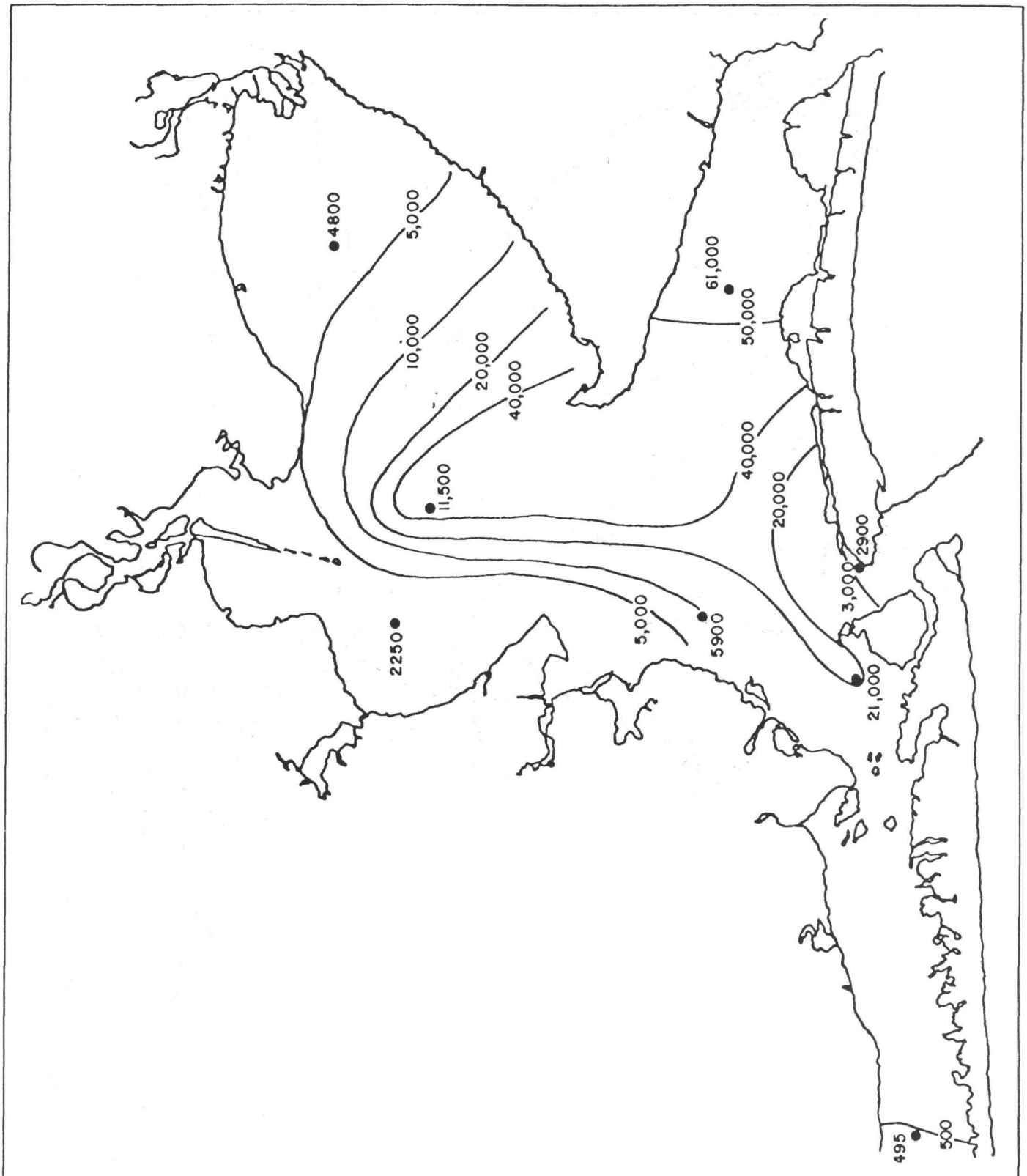
Values are number of cells per 100 ml.

Figure 18

October, 1969 Phytoplankton Populations

Galveston Bay System

JONES AND NEUSE, INC.
Environmental and Engineering Services



From: UTMSI, 1973. "Toxicity Studies of Galveston Bay Project"

* Contours produced from data obtained from Copeland, 1970

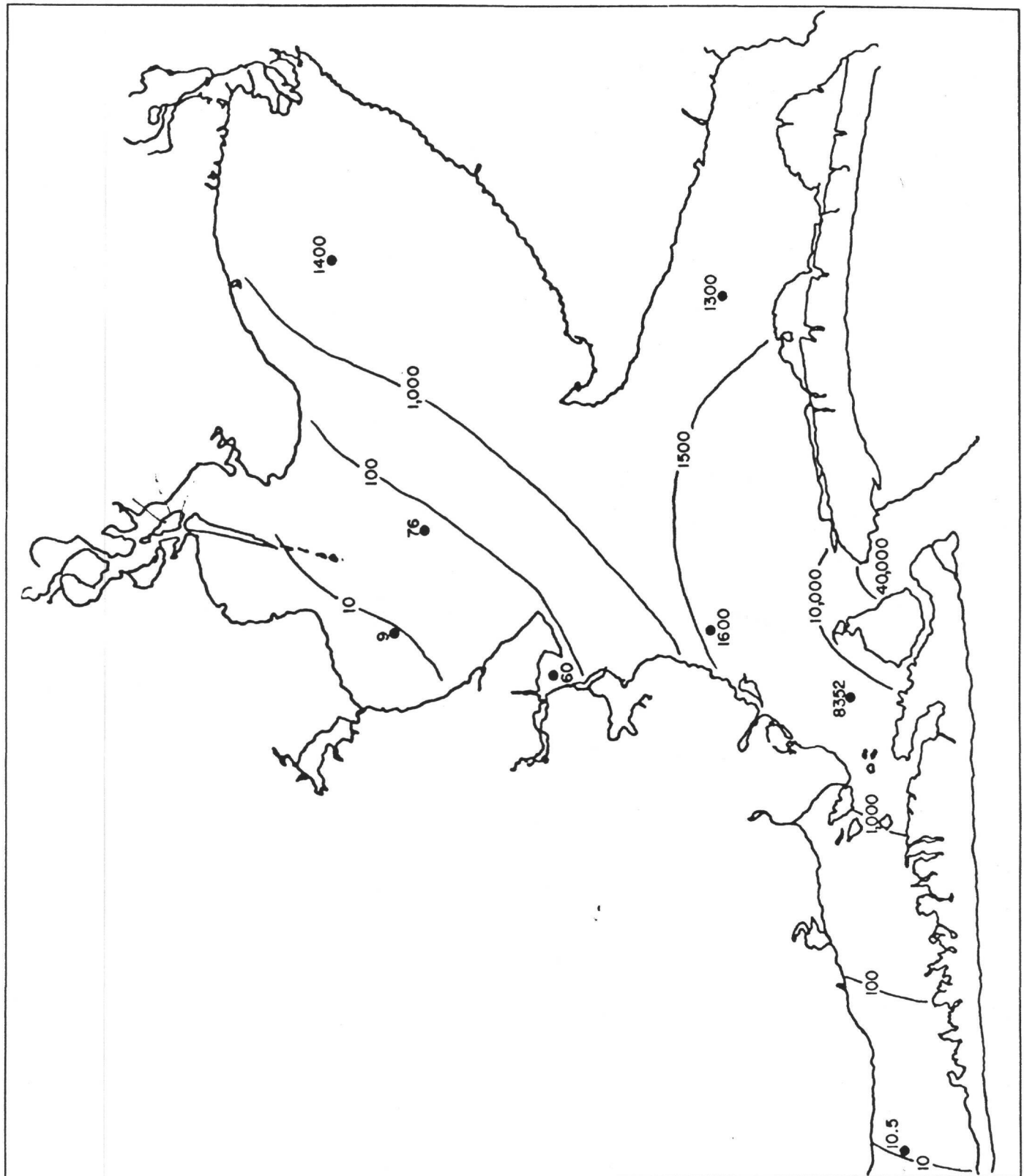
Values are in number of cells per 100 ml.

Figure 19

February, 1969 Phytoplankton Populations

Galveston Bay System

JONES AND NEUSE, INC.
Environmental and Engineering Services



From: UTMSI, 1973, "Toxicity Studies of Galveston Bay Project"

* Contours produced from data obtained from Copeland, 1970

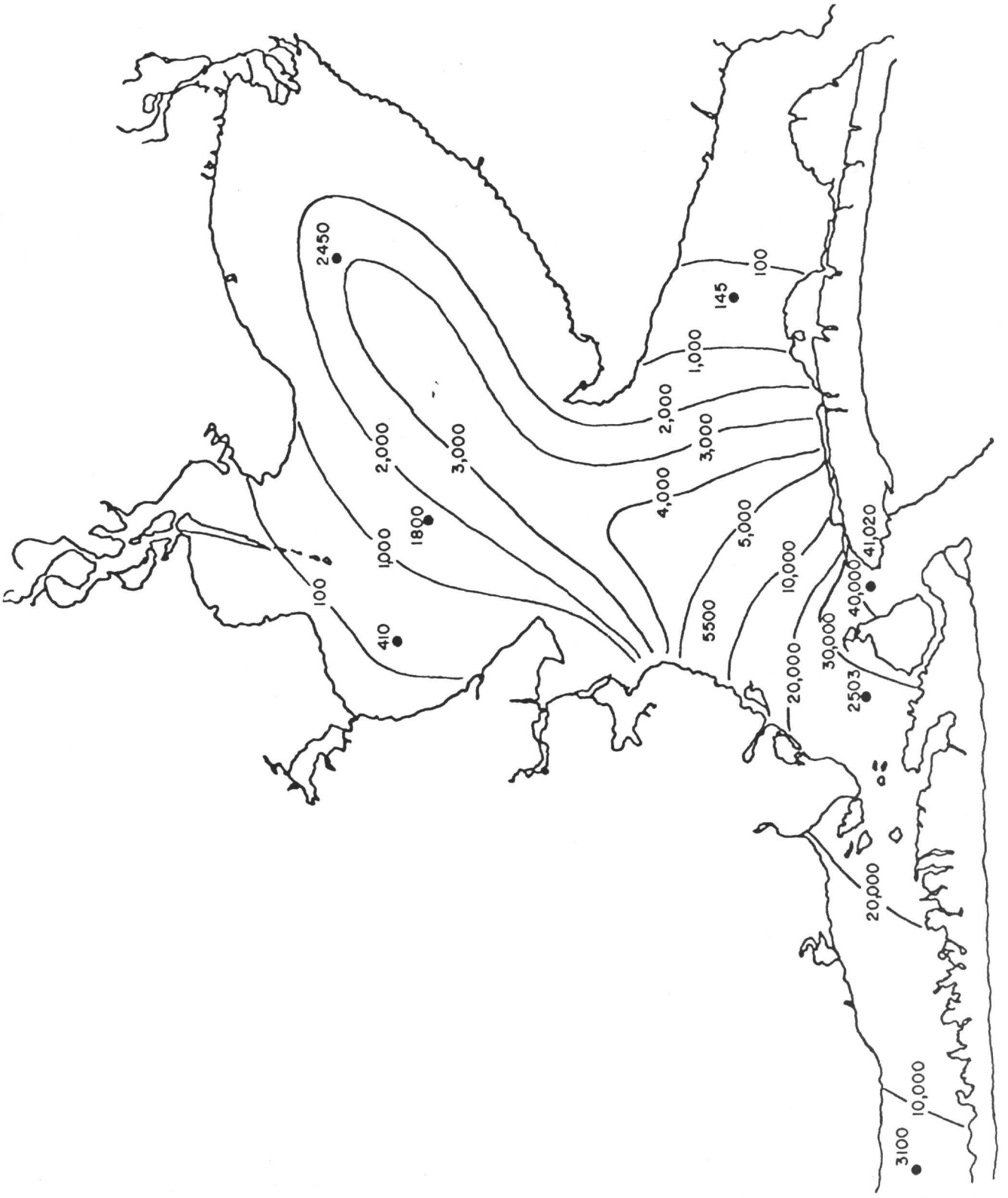
Values are number of cells per 100 ml.

Figure 20

April, 1969 Phytoplankton Populations

Galveston Bay System

JONES AND NEUSE, INC.
Environmental and Engineering Services



From: UTMSI, 1973, "Toxicity Studies of Galveston Bay Project"

* Contours produced from data obtained from Copeland, 1970

Values are in number of cells per 100 ml.

Figure 21

July, 1969 Phytoplankton Populations

Galveston Bay System

JONES AND NEUSE, INC.
Environmental and Engineering Services

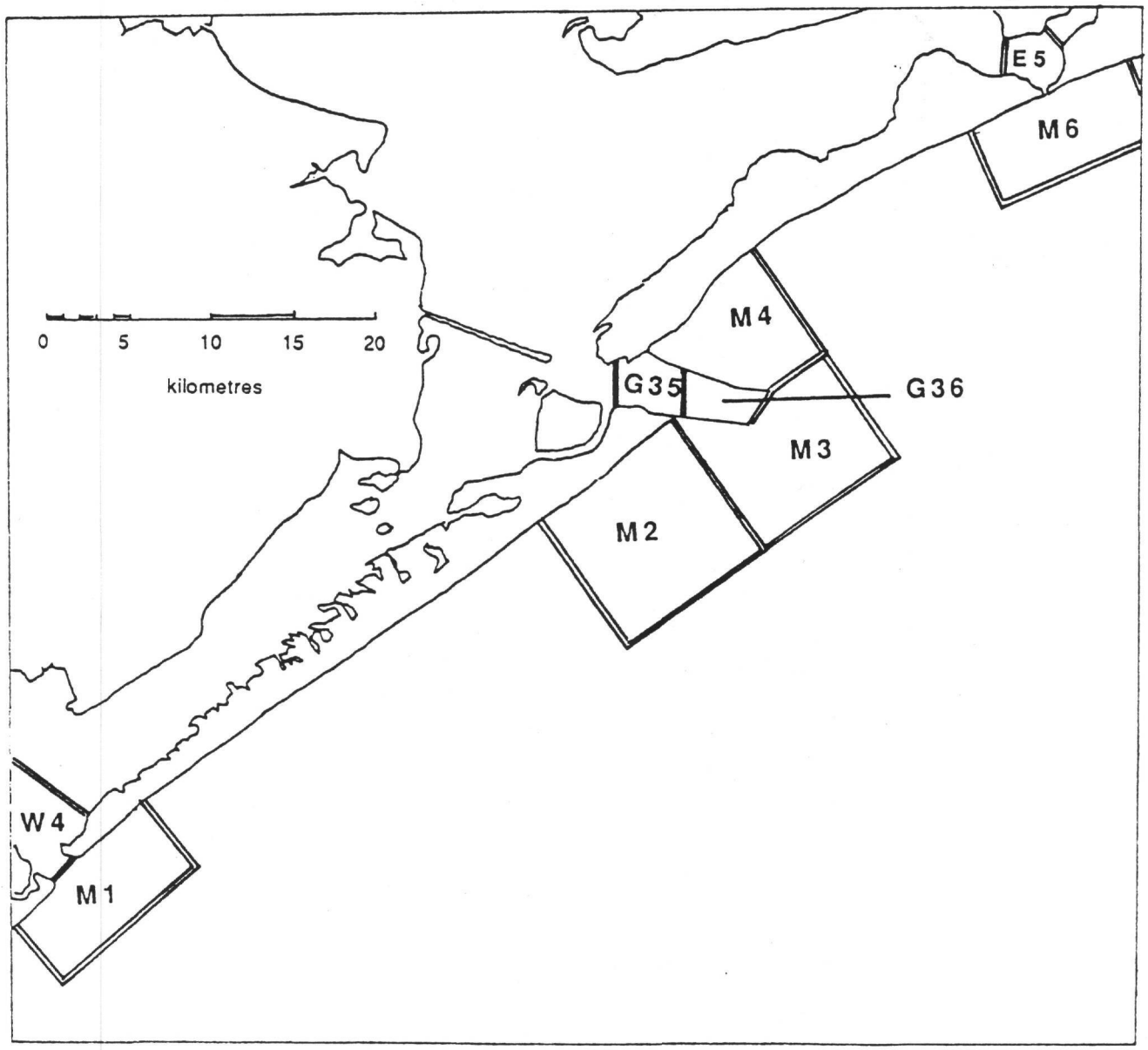


Figure 22
Hydrographic Segmentation Map
Near-shore Gulf of Mexico
Galveston Bay Area

From: Ward, 1991, "Hydrographic Segmentation for Galveston Bay"

JONES AND NEUSE, INC.
Environmental and Engineering Services

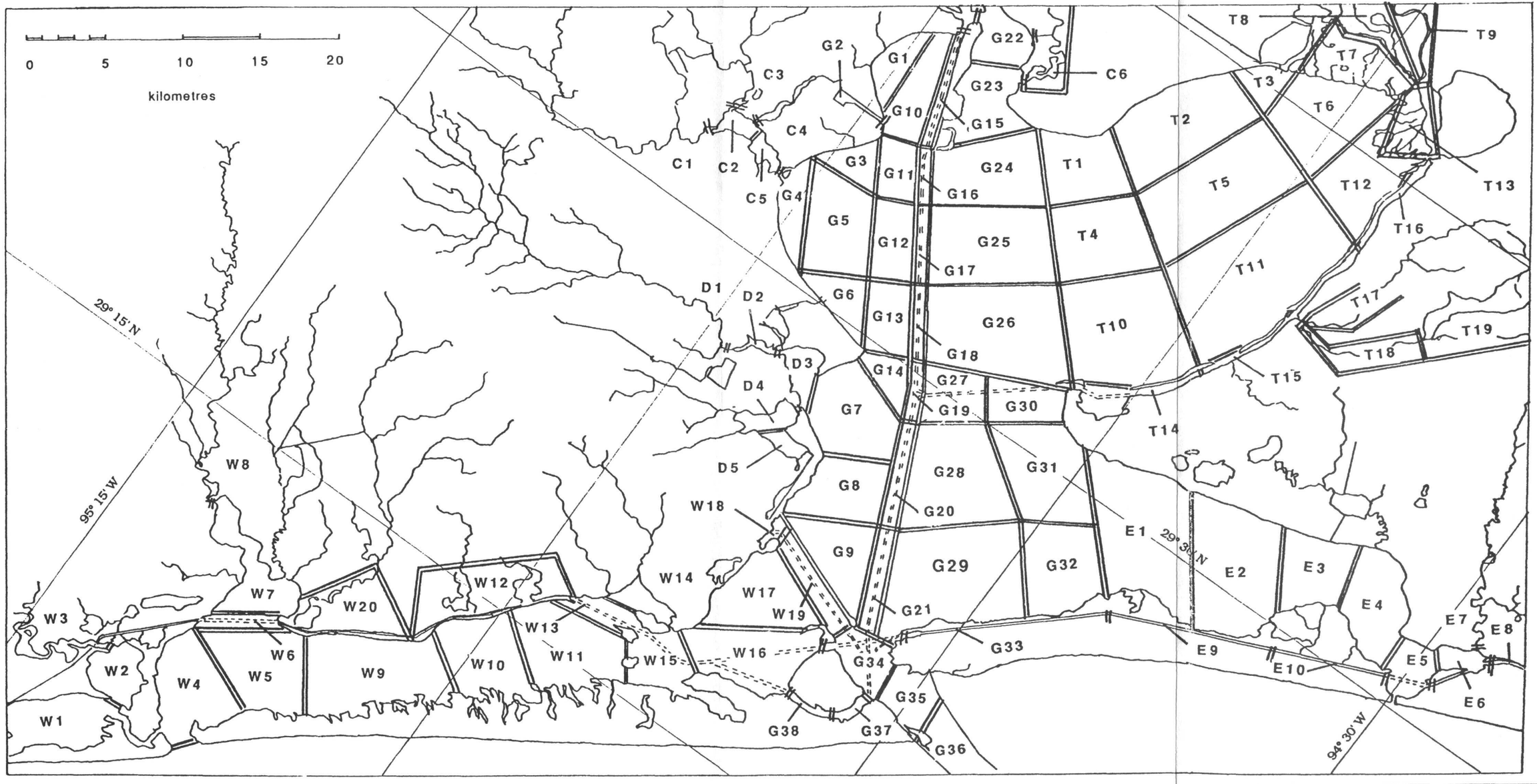


Figure 23

Hydrographic Segmentation Map

Galveston Bay

From: Ward, 1991, "Project Memorandum – Hydrographic Segmentation for Galveston Bay"

JONES AND NEUSE, INC.
Engineering and Environmental Consultants

Galveston Bay National Estuary Program

MUD	% MUD
Mud (M)	> 75%
Sandy mud (SM)	50–75%
Shelly Mud	50–75%
Sandy shelly mud Shelly sandy mud	< 50% < 50%

SAND	% SAND
Sand (S)	> 75%
Muddy sand (MS)	50–75%
Shelly sand	50–75%
Muddy shelly sand Shelly muddy sand	< 50% < 50%

SHELL and GRAVEL	%
Shell and rock Fragment gravel (G)	> 75%
Muddy shell	50–75%
Sandy shell	50–75%
Sandy muddy shell Muddy sandy shell	< 50% < 50%
Reef, oyster (Location based on (information sampling program)	

SCALE: 1:250000

0 1 2 3 4 5 6 7 8 9 10 KILOMETERS

0 1 2 3 4 5 6 MILES

TRINITY BAY
EAST BAY
GALVESTON BAY
WEST BAY
CHOCOLATE BAY
CHRISTMAS BAY
GULF OF MEXICO
Lake Anahuac
Clear Lake
Dollar Point
Jamaica Beach
Trinity River
Old River
Cotton Bayou
Barbers Hill Canal
Goose Creek
East Fork
Cedar Bayou
Spring Gully
Big Island Slough
Dayton Lateral
Horsepen Bayou
Clear Creek
American Canal
Dickinson Bayou
Mustang Bayou
Pleasure Bayou
Briscoe Canal
Moses Bayou
Highland Bayou
Bastrop Bayou
Carancahua Bayou
Hall's Bayou
Persimmon Bayou
New Bayou
Salt Bayou
Whorton Bayou
West Fork Double Bayou
East Fork Double Bayou
Oyster Bayou
29°30'30"N
29°45'00"N
29°37'30"N
29°22'30"N
29°15'00"N
29°00'00"N
95°15'00"W
95°07'30"W
95°00'00"W
94°52'30"W
94°45'00"W
94°37'30"W

Source: The University of Texas at Austin
Bureau of Economic Geology
Submerged lands of Texas
Galveston–Houston area
Plate 1. Surface sediment distribution

FIGURE – 25
SEDIMENT TEXTURE MAP – GRAVEL, SAND & MUD DISTRIBUTION IN RELATIVE PERCENT
SHEET 1 OF 1

JONES AND NEUSE, INC.
Environmental and Engineering Services

Galveston Bay National Estuary Program

CLAY	% CLAY
Clay (C)	> 75%
Silty clay	50–75%
Sandy clay	50–75%
Sand–silt–clay	< 50%

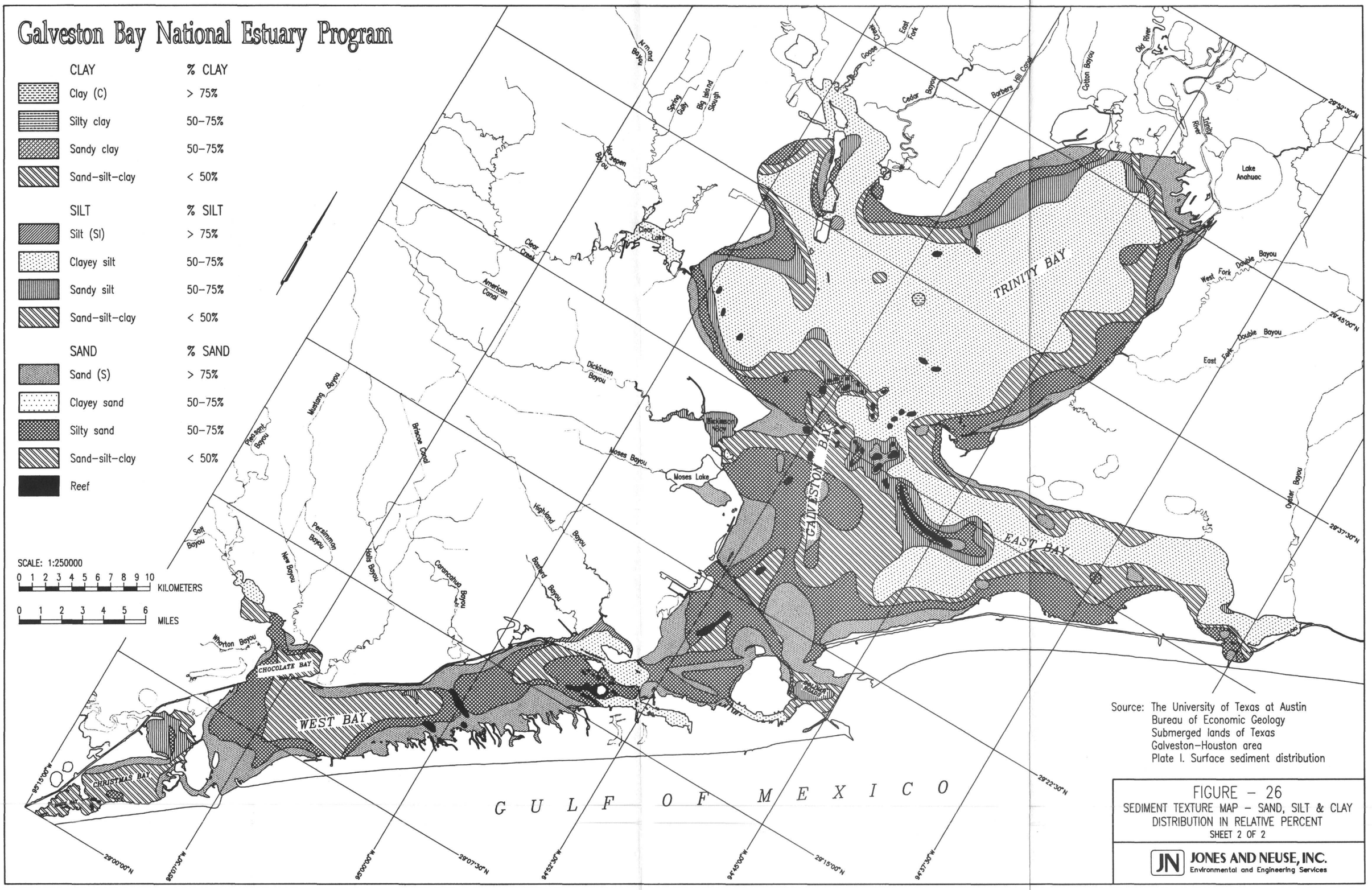
SILT	% SILT
Silt (SI)	> 75%
Clayey silt	50–75%
Sandy silt	50–75%
Sand–silt–clay	< 50%

SAND	% SAND
Sand (S)	> 75%
Clayey sand	50–75%
Silty sand	50–75%
Sand–silt–clay	< 50%
Reef	

SCALE: 1:250000

0 1 2 3 4 5 6 7 8 9 10 KILOMETERS

0 1 2 3 4 5 6 MILES



Source: The University of Texas at Austin
Bureau of Economic Geology
Submerged lands of Texas
Galveston–Houston area
Plate I. Surface sediment distribution

FIGURE – 26
SEDIMENT TEXTURE MAP – SAND, SILT & CLAY DISTRIBUTION IN RELATIVE PERCENT
SHEET 2 OF 2

JONES AND NEUSE, INC.
Environmental and Engineering Services

Galveston Bay National Estuary Program

SCALE: 1:250000

0 1 2 3 4 5 6 7 8 9 10 KILOMETERS

0 1 2 3 4 5 6 MILES

LEGEND

County Boundary

City/Municipal Boundary

Harris County

Brazoria County

Chambers County

Galveston County

Pasadena

Baytown

La Porte

Shoreacres

Seabrook

League City

Texas City

Tiki Island

Galveston

Jamaica Beach

TRINITY BAY

EAST BAY

WEST BAY

CHOCOLATE BAY

CHRISTMAS BAY

GALVESTON BAY

BOLIVAR ROADS

G U L F O F M E X I C O

Armand Bayou

Spring Gully

Big Island Slough

Goose Creek

East Fork

Cedar Bayou

Barbers Hill Canal

Cotton Bayou

Old River

Trinity River

Lake Anahuac

Hog Pen Bayou

Clear Lake

Clear Creek

American Canal

Dickinson Bayou

Dickinson Bay

Moses Bayou

Moses Lake

Mustang Bayou

Pred Sant Bayou

Briscoe Canal

Salt Bayou

Persimmon Bayou

New Bayou

Halls Bayou

Corrancahua Bayou

Highland Bayou

Bastrop Bayou

Whorton Bayou

West Fork Double Bayou

Double Bayou

East Fork Double Bayou

Oyster Bayou

29°52'30"N

29°45'00"N

29°37'30"N

29°30'00"N

29°22'30"N

29°15'00"N

29°07'30"N

29°00'00"N

94°30'00"W

94°37'30"W

94°45'00"W

94°52'30"W

95°00'00"W

95°07'30"W

95°15'00"W

FIGURE – 27

COUNTY AND JURISDICTIONAL BOUNDARIES
GALVESTON BAY AREA

JONES AND NEUSE, INC.
Environmental and Engineering Services